EXCERPT FROM A REVIEW

Ivica Kisic, full-time professor

Faculty of Agriculture, University of Zagreb

The proposed manuscript is a very valuable, studious and comprehensively prepared work, which students from the fields of natural, technical and biotechnical sciences and other similar professions in undergraduate and graduate studies need. I consider no less important the fact that this work can usefully serve any graduate engineer and young scientist, as a valuable source of information on land protection.

At a time when it is not easy to find motivation for this type of activity (publishing books), reputable scientists have invested great and valuable effort and time in the pages before us. They prepared a piece of work of an undeniably great value, a work which clearly shows how to mitigate or suppress the processes that threaten the degradation of land in Bosnia and Herzegovina.

In addition to students, the book will find its readers among all persons responsible for making strategic development decisions related to proper use of land in Bosnia and Herzegovina. No less important is the recommendation that all those who deal with land in their work should read this book with the aim to educate themselves about the importance and irreplaceability of land.

Emira Hukic, Assistant Professor

Faculty of Forestry, University of Sarajevo

A search on Google Scholar portal indicates about 2.4 million of publications of all types that have the term „sustainable land management“ in their title or contents. In addition to the original approach to general topics of sustainable development and especially sustainable land management, an undoubted originality to this work is given by the meticulous depictions of concrete technologies for sustainable land management which the authors now present to the public after a detailed and demanding field research.

The proposed work for publication, in its concept and primary purpose, falls into the category of a scientific book which offers elaborated modern scientific achievements in the field of sustainable land management, but also a number of topics directly related to understanding and applying the concepts of sustainable development in general, and especially sustainable development of agriculture and food production.

This publication can be of extreme benefit to a wide range of readers – from students of practically all so-called life science studies, through agronomic and agricultural experts in production, to persons responsible at all levels of management and decision-making in relation to preservation or improvement of the state of all, and especially agricultural and forest lands. As already mentioned, the books has an undoubted potential to be recommended as supplementary literature for a number of university subjects dealing with land, and especially with sustainable land management and rural areas.

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SUSTAINABLE LAND MANAGEMENT – APPROACHES AND PRACTICES IN BOSNIA AND HERZEGOVINA

Hamid Čustović, Melisa Ljuša, Stefan Schlingloff

Milenko Blesić, Muhamed Bajrić, Dragana Ognjenović, Mirha Đikić, Nicole Harari, Rima Mekdaschi Studer, Dragica Tešić, Amra Imamović, Ejub Trako, Sabina Hodžić, Mehmed Cero, Marija Proleta, Amina Salihagić

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Sarajevo, 2020

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LIST OF ABBREVIATIONS

BHAS	Agency for statistics of Bosnia and Herzegovina
BHMAC	Bosnia and Herzegovina Mine Action Centre
CLC	Corine Land Cover
CORINE	Coordination of Information on the Environment
DS-SLM	Decision Support for Mainstreaming and Scaling up of Sustainable Land Management
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
IPCC	Intergovernmental Panel on Climate Change
LDN	Land Degradation Neutrality
MoFTER	Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina
OECD	Organization for Economic Cooperation and Development
PAH	Polycyclic Aromatic Hydrocarbons
PLUD	Participatory Land Use Development
SDG	Sustainable Development Goals
SLM	Sustainable Land Management
SPI	Standardized Precipitation Index
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WOCAT	World Overview of Conservation Approaches and Technologies

PREFACE

Numbers can sometimes tell a compelling story. The UNCCD brochure „Land in numbers 2019. Risks and Opportunities“ uses numerical indicators to draw attention to the situation and problems associated with land degradation, as well as importance and possibility of sustainable management of this indispensable and hard to repair resource. Some of the land degradation indicators at the global level from this brochure are presented here.

Over two billion hectares of land (twice the area of China) are currently degraded worldwide, having small economic and environmental value. Out of the total land area on Earth, 71% is defined as inhabited, while glaciers and unfertile soil account for the remaining 29%. Half of the land area is used in agriculture for supplying 99.7% of total food (calories) requirements, 83% of which is a plant-based diet. Approximately 44% of the world ‘s agricultural land is located in arid areas providing 60% of world food production mainly in Africa and Asia. Currently, 30-45% of land areas is used in animal husbandry as pastures and for animal feed production. Over the last fifty years, the requirement for animal products has considerably increased, resulting in an increase in the use of agricultural land by approximately 65%. Today more than half of the world’s population lives in urban areas accounting for only 1% of the land surface. On the other hand, it often happens that the land area required for supplying a city with food, energy, and resources is twenty times the area of the city itself.

Generally speaking, Bosnia and Herzegovina has very little agricultural land of good quality. Of the entire area of Bosnia and Herzegovina, the top three bonity categories account for only 14.2%. The land is under permanent anthropogenic pressure. Increasingly growing population in urban municipalities and the use of land for housing, infrastructure, and industrial purposes are some of the major drivers. The land use change from agricultural into building occurs on an almost daily basis, where even the most fertile land is converted into building land. In rural areas, the devastation of space occurs due to deagrarization, where the abandoned land is left exposed to natural processes, which result in complete destruction of the agricultural landscape that took ages to evolve. The space is exposed to erosion, various forms of devastation, and the spread of invasive species. Climate change additionally accelerates these processes, particularly concerning drought at higher altitudes and in the area of Dinarides. Illegal and uncontrolled felling contributes to the degradation of forestland. Some watercourses regularly cause floods. These phenomena are becoming increasingly frequent as a result of climate change.

According to the CORINE data (mapped change >5 ha), total reduction in agricultural land in the period 2000-2018 amounts to 14,152 hectares or 786 ha/year.

The situation at local level is considerably different and incomparably worse.

Based on the analysis of ortho-photo images in the period 2008-2012 (mapped change >1 ha), on the area of only three municipalities: Banovići, Kladanj and Tuzla, 32.5 hectares of agricultural land was converted into built-up areas and the area of land under forest succession increased by 159 ha. This example shows the importance of having indicators for monitoring at the local level as well as the significance of the scale of monitoring this change.

Currently, there are more than 800 million malnourished people worldwide, and by 2050, global food production should increase by 50% in order to provide food to the expected population of more than 9 billion. The question is how we are going to meet these ever-growing requirements for food if it is estimated that land degradation and climate change combined will reduce crop yields by an average of 10% at a global level, and by as much as 50% in certain regions. Degradation of land and other natural resources is not just an environmental responsibility, but a social and economic threat to many countries.

Despite ominous projections, there is still room for discussing opportunities as well. There has never been a better chance of investing in the restoration of degraded land and landscapes for us and future generations. Authorities, particularly in undeveloped and developing countries should know that many initiatives for the rehabilitation of degraded land and their conservation have been launched at a global level. The “New decade on ecosystem restoration” program has been adopted in the UN. Within the Sustainable management goals, particularly target 15.3 – a land degradation neutrality concept was accepted. Built upon it are numerous other initiatives such as the Bonn Challenge, the New York Declaration on Forests, and the African forest landscape restoration initiative. These new initiatives open the space and provide opportunities for big changes in the area of sustainable land management at a global level.

The restoration of degraded landscapes and rural areas has the potential for becoming a new business paradigm, the so-called economic reconstruction. New business models are emerging, technology is advancing and world governments are showing political will. This is great news for investors seeking opportunities for economic growth. It is also great news for the economy, job opportunities, safety of food, and planet Earth. By protecting, securing, and rehabilitating the key ecosystems, we can provide a safer future for generations to come.

For all these reasons, we thought that the preparation of such a book whose authors would try to explain the issues of sustainable land management in a simple and practical way given that this resource, being vital to the existence of future generations, is under permanent pressure of degradation processes and disappearance, would be a necessity.

Lastly, I want to thank all my associates for their dedicated work during the implementation of the project and preparation of this book.

Prof. Hamid Čustović

FOREWORD

The broader picture of the state of natural resources on Earth is very complex. Natural resources such as land, water, and biodiversity are the most important components of life and are crucial for all aspects of sustainable development. These key assets are increasingly being undermined by mismanagement, be it soil, biodiversity loss, water pollution, or the effects of climate change that reduce their quantity and degrade their quality. However, it should be emphasized here that land resources are under particular pressure in terms of increasing degradation and desertification in almost all countries due to the many different factors affecting its ecological and production functions. One of the most important factors affecting the state of the land is the increasing demand for food, both in terms of quantity (kilojoules of energy) and quality (share of animal protein in the diet).

Arable, fertile land is increasingly exposed to the pressure associated with building infrastructure, expanding urban settlements, and using it for other purposes that are not in the function of food production. Recently, agricultural land has been used for biofuel production to a considerable extent. The effects of degradation on soil biodiversity are becoming increasingly present in terms of reduced growth and productivity in the production of certain crops due to a decrease in its natural fertility potential, energy loss, impact on soil health status, and other degradation processes.

In addition to anthropogenic, the status and potential of land resources are greatly influenced by natural factors such as climate variability and extreme weather events, which are manifested as floods and droughts, storms, erosion processes, and landslides as a result of the construction of infrastructure and housing facilities in such terrains, along with the increasing presence of excessive precipitation per unit time.

Various forms of ever-bigger losses of fertile agricultural land caused by population growth, urbanization, climate change, land degradation and desertification, threaten the safety of food production required for human and animal wellbeing worldwide.

In many underdeveloped and developing countries, in addition to land degradation and desertification issues, there are also issues associated with security of tenure and access to land rights which significantly contribute to increased population migration, gender inequality, and increasing income inequality in many regions. The land policy pursued in a particular country as well as how land resources are managed also have a serious impact on this situation.

High demand for agricultural products and raw materials produced on land is under adverse social and economic conditions and a lack of adequate investment. This situation puts pressure on decision-makers to move towards prioritizing short-term land use purposes rather than long-term ones, which means preserving or increasing their potential fertility and thus sustainability in the production of food and biomass in general, for the needs of the population and future generations. Such a prevailing short-term approach creates a disparity between the market price and the real economic value of the land, which often leads to its further overexploitation and, consequently, degradation.

As the amount of arable land is fixed, it is quite clear that its quality or production capacity must be enhanced, improved and preserved for future generations; otherwise, the natural forest and aquatic ecosystem will have to be converted into agricultural land, which will have irreversible consequences on the state of biodiversity and impact on the acceleration of climate change.

What future scenarios concerning this resource can be expected, given that we are faced with new and increasing challenges that have arisen because of changing land use?

Land use change is most often associated with rapid and unplanned urbanization, intensive exploitation of raw materials, particularly in mining and generally in the production of solid fuel energy or hydro-accumulation, deforestation, population growth, mass migrations, expansion of agriculture due to increasing demand for food and raw materials accompanied by the increase in standards of living and construction of massive infrastructure. The increasing incidence of extreme weather conditions and projected climate change are likely to exacerbate the extent and scope of land degradation and water scarcity in many parts of the world.

Expected population growth is increasingly reducing the arable land per capita that could be used for meeting the pronounced requirements and demand for various products associated with new consumer trends.

There is an increasing number of stakeholders considering land as a resource, which can lead to conflicts within complex governance structures. It is a realistic projection that instability and conflicts among actors regarding limited resources will further increase, both globally and regionally. Increased scarcity in food and water availability, healthy soil and disturbed biodiversity lead to increased poverty, conflicts, migrations and instability, even wars in many parts of the world.

In order to avoid negative consequences, it is necessary to have a solution plan, the most important being timely planning and encouraging significant change in the way we use and manage land resources. The solution plan should provide synergy between land-use planning and management practices which should optimize a wide range of benefits across all sectors and all stakeholders within a strong „business environment".

Land use or spatial planning, based on laws and regulations, is the best path to conserving land resources and providing advanced solutions thus creating responsibilities and minimizing land degradation trends, by addressing the drivers (causes) and impacts rather than consequences. Protecting intact natural ecosystems such as forests, pastures, and natural meadows, and preserving their resilience, requires serious planning, an efficient management structure, and an integrated landscape management strategy. Without a synergistic approach and the overall concept of rural development on a long-term basis, it is difficult to expect any beneficial effects on protecting land resources. This further means that different land management policies and strategies need to be implemented on a sustainable basis so that they are flexible and include many different instruments aimed at reversing land degradation trends towards preserving the land for the well-being of the planet Earth and for generations to come. Incidentally, degraded land, where possible, needs to be restored, rehabilitated, or converted into biologically and/or economically productive areas that will generate direct benefits to the land user and prevent further conversion of this ecosystem.

This concept is also envisaged under the United Nations Convention to Combat Desertification (UNCCD) through Land Degradation Neutrality (LDN), which Bosnia and Herzegovina has accepted as its approach voluntarily.

Planned solutions will require investment in rural development, aimed at making rural space more attractive to young people, creating desirable job opportunities, providing much-needed infrastructure, and reducing the stress associated with migration from village to town. Ensuring gender rights and equality should be an integral part of the institutional and governance capacities required at all levels to ensure a sustainable lifestyle and stability in rural areas.

As part of the solution, the implementation of sustainable land management (SLM) best practices should gradually increase. The loss of healthy and productive land is a limiting factor in the effort to meet the challenges of securing sufficient quantities of food, water, and energy for the increasingly demanding needs of the population worldwide.

Sustainable land management implies the application of traditional and modern practices for maintaining or enhancing soil fertility, water efficiency, and conservation of biodiversity on and in the soil. Only healthy and productive land within a terrestrial ecosystem is capable of providing a wide range of useful functions and services.

Sustainable land management technologies and approaches include a long-term vision of integrated management of natural resources at all levels, with the aim of connecting the situation at the local level with the context of landscape appearance. With this approach, land users and managers can optimize compromise solutions using practices that increase resilience and create successful natural cycles and relationships for the benefit of man and nature.

Given the magnitude and impact of land degradation worldwide, there is an urgent need to introduce proven good and cost-effective SLM practices that will improve living conditions, increase resilience to ever-present climate change, reduce conflicts and contribute to the achievement of numerous Sustainable Development Goals (SDG). The gradual introduction of SLM practices at the local level, should imply their reproduction and dissemination at regional, river basin or landscape levels to support the future growth and prosperity of a particular area or region, prevent the outflow of population from rural areas, and ensure the prerequisites for new generations of the population who have increasingly high and selective demands for food and the environment.

Stopping and reversing the trend of land degradation through the LDN concept has been accepted by a large number of countries worldwide. The trend should stop by 2030 (SDG 15.3.) through planning future degradation and restoring previously degraded land in the same qualitative and quantitative scope.

The goals are global, but implementation and commitments take place locally, with the active support of the state. To take advantage of this momentum, both private and public sectors should, as part of their commitments to the 2030 Agenda for Sustainable Development, promote this concept and provide incentives for cooperation between different sectors.

This cooperation requires innovative and lasting partnerships, as well as equitable and inclusive governance institutions, to ensure that SLM practices at the required levels are effectively integrated into development goals within investment plans and strategies.

Some SLM practices and technologies can provide tangible benefits in the short run. However, it must be borne in mind that their importance and contribution to society lies in transforming our way of overcoming the long-term challenges of poverty, food and water safety and generally contribute to the well-being of humans and animals.

At this historical juncture, call for action appears to be necessary. Anyone can contribute, and all of us have our own role we should be worthy of as human beings. Anyone can be a champion for change, and we need to find the required resources, at any level, to think long-term, to communicate and implement a transformative vision, bring different groups together, encourage a new way of dealing with the land and the land area.

INTRODUCTION 1

1.1. Sustainable Land Management Definitions

The term sustainable land management includes the terms „sustainable“ and „land“ which, due to their diverse use and interpretations, need to be contextualized for this purpose. Before we do that, it should be noted that the concept of sustainable land management was first mentioned in the early nineties of the last century. This approach was of an ongoing interest in both research and public communication. This is best confirmed by the number of published studies on this topic indexed by the *Web of Science*, which in 1990 amounted to about 100, and raised to about 1,600 in 2016 (Sanz *et al*., 2017). Sustainable land management is somewhat differently defined in different places and for different purposes, and only some of the definitions of sustainable land management will be mentioned here. The World Bank (2006) defines sustainable land management as:

„SLM is defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods“.

The United Nations Economic Commission for Europe (UNECE) does not use the term „sustainable“ in its definition (1996) but implies that:

„Land management is the process by which the resources of the land are put to good effect. It covers all activities concerned with the management of land as a resource both from an environmental and from an economic perspective. It can include farming, mineral extraction, property and estate management, and the physical planning of towns and the countryside“.

A comprehensive and commonly accepted definition in agronomic circles was adopted at the UN Earth Summit in 1992 (Sanz *et al*., 2017) according to which sustainable land management means:

„The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions".

This definition of sustainable land management is used by the FAO – Food and Agriculture Organization of the United Nations and the global WOCAT network – The World Overview of Conservation Approaches and Technologies.

The concepts and definitions of „sustainability" in relation to natural resources management have changed over time. Today, sustainable land management, as underlined by the UN Earth Summit definition underlines, implies a holistic approach, while maintaining all functions of land, as well as preserving and enhancing the functionality of the ecosystem as a whole.

In this regard, new concepts emerge that are directly or indirectly related to land use, such as ecosystem functions; ecosystem approaches; ecosystem-based adaptations; integrated management, etc. It should be emphasized that all these concepts, although they may have different purposes, stress sustainable interactions between natural ecosystems and the social-economic demands of the population.

Land degradation

Land degradation is commonly understood as the consequences of multiple processes that directly or indirectly diminish its functions, most often in food production. FAO defines land degradation as:

„The process of reducing the actual or potential capacity of land to produce resources and maintain its natural functions".

The term „land degradation" is often confused with the term „soil degradation" which can be understood, as soil degradation is truly the most common land degradation process. For example, European Union documents address only eight groups of soil degradation (erosion, contamination, salinization, soil organic matter decline, soil sealing due to the construction of housing and infrastructural facilities, landslides, soil compaction, and reduction of soil biodiversity)[1].

[1] Commission of The European Communities. Thematic Strategy for Soil Protection: Impact assessment of the thematic strategy on soil protection. Commission staff working document, Document accompanying the Communication from the Commission

Degradation can be caused by physical, chemical, and biological changes due to environmental, social, and/or economic pressures, and the level of degradation depends also depends on the soil's resilience to change. The complexity of the possible causes of degradation and the properties of soil that resist potential degradation makes it difficult to define the true causes of degradation. As this is a complex and interconnected process, effective control and monitoring of these processes are needed for preventing negative effects.

The differences between land degradation and desertification should also be noted. Desertification is the result of long-term interactions of various land degradation processes that are usually faster in dry, arid regions, although desertification can occur in all climates.

From the viewpoint of some agricultural practices, soils having less than 1.7% organic matter are considered to be in the pre-desertification stage. UNEP - United Nations Environment Programme and FAO define desertification as „degradation in arid, semi-arid and semi-humid areas resulting from anthropogenic activities“.

Although this definition of desertification has been adopted by UNCCD (United Nations Convention to Combat Desertification), it must be said that desertification can occur in all conditions (e.g. large areas in Iceland have been converted to desertified areas due to loss of soil and organic matter).

Unlike desertification, as a consequence of human activities aided by some natural processes, climate change, in particular, the desert is a natural state and it is not the subject of this discussion.

1.2. Land Degradation Types

Within the WOCAT platform and the network developed for SLM approaches and technologies, the questionnaires used to define the cause and extent of land degradation distinguish five types and twenty-six sub-types of land degradation. The key types of land degradation are as follows:

- Soil erosion by water (W - *water*),
- Soil erosion by wind (E - *aeolian*),
- Chemical soil deterioration (C - *carbon*),

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to the Council, the European Parliament, the European Economic and Social Committee and the Committee Of The Regions, COM(2006)231 final, SEC(2006)1165. SEC(2006)620, Brussels, 22.09.2006.

- Biological degradation (B - *biological*),
- Hydrological degradation (H - *hydrological*).

Soil erosion by water (W) is one of the most severe forms of land degradation, where these forms can range from sporadic to catastrophic. In Bosnia and Herzegovina, water erosion is very much present as it is a hilly-mountainous country, for the most part of a karst character and with over 70% of the total area exceeding the inclination of 13%. All forms of water erosion are represented, including:

Wt *(t – topsoil):* displacement of the upper layer of soil – topsoil erosion

Wg *(g – gullying):* gully erosion

Wm *(m – movements):* mass movement of soil – landslide

Wr *(r – riverbank):* river banks erosion

Wc *(c – coastal):* coastal erosion

Wo *(o – offsite):* off-site effects of degradation: movement of sediments, downstream flooding, siltation of water reservoirs and watercourses, pollution of water bodies with eroded sediments.

Erosion by wind (E) or aeolian erosion is the predominant process of land degradation in arid and semi-arid regions. In desert parts, it is the major process and cause of desertification. Wind erosion forms can vary in terms of displacement and deposition of eroded material. The following forms should be distinguished:

Et *(t – topsoil):* uniform loss of the upper layer of soil

Ed *(d – deflation and deposition):* deflation and deposition, and uneven loss of the topsoil, thus creating concave and convex forms of relief

Eo *(o – offsite):* off-site effects of degradation: covering the terrain with airborne dust particles or sand

Chemical soil deterioration (C) is one of the most serious degradation problems, which largely depends on the use of soil, its buffer and adsorptive capacity to resist change, and the type of contaminants.

Some of the problems associated with degradation of soil chemical properties can be relatively easily remedied, e.g. by increasing soil fertility (enrichment with nutrients and organic matter), while some others degradation processes require much more effort and time to eliminate (e.g. the presence of heavy metals, polycyclic aromatic hydrocarbons, and pesticide residues). The agents of chemical soil degradation can be divided into the following groups:

Cn *(n - fertility decline and reduced organic matter content):* fertility decline and reduced organic matter content (not caused by erosion), for example, leaching, nutrient oxidation and volatilization

Ca *(a – acidification):* acidification: lowering of the soil pH through vertical leaching of light soils

Cp *(p – pollution):* contamination of the soil with toxic substances (heavy metals, organic pollutants, and pesticide residues, and radioactive substances)

Cs *(s – salinization/alkalization):* salinization and alkalization, being two interrelated processes, are typical of arid regions and irrigation conditions. Salinization primarily means that there is a net increase in the concentration of soluble salts in the topsoil (salinization process) or an increase in the total amount of Na^{+} in the soil adsorptive complex, causing alkalization of soil and desertification as the ultimate consequence and the most severe form of soil degradation (formation of an anthropogenic desert). Both of these processes are adverse, with alkalization being a much more adverse process leading to the destruction of both chemical and physical properties of the soil. The accumulation of salts in the soil results in increased osmotic pressure that the roots of agricultural plants can hardly cope with. In the salinization process, yields are significantly reduced depending on the type of crop, while in alkalization there is no possibility of productive and rational production.

Biological degradation (B) is a widely known and accepted process in which change and losses of biodiversity of plants and animals has occurred. It is mainly referred to a decline or disappearance of some form of life on the land, in the soil and water, which can be classified as:

Bc *(c – cover):* the decline of vegetation cover and increase of bare and unprotected soil as a result of deforestation, overgrazing or some human activities on the land surface

Bh *(h – habitats):* loss of entire habitats through the disappearance of plant diversity and increased fragmentation of habitats, most often as a result of abandoning the anthropogenic space, i.e. moving from rural hilly-mountainous regions to cities and flatlands

Bq *(q – quantity/biomass decline):* reduction of biomass per unit area, in other words, reduction of crop production, as a result of poor agricultural practices, inadequate seed and animal breed composition, or the impact of climate change and disturbance on production cycles

Bf *(f – fires):* biological detrimental effects of all types of fires; wildfires, burning of crop residues after harvest, as well as other types of burning organic residues on the soil surface

The negative effects of fires and burning are reflected in the direct impact on soil through the immediate destruction of surface and sub-surface biodiversity, after which, during the rainy season, excessive erosion occurs. Besides, burning releases large amounts of gases into the atmosphere in the form of CO_2, which has the most direct effect on the increase of greenhouse gases (GHG), and warming of the atmosphere.

Bs *(s – species):* quality and species composition/diversity decline: loss of natural species, perennial crops, spreading of invasive species and weeds, etc., have been increasingly present in anthopogenized rural areas due to the migration of population associated with hardships of rural lifestyle and social differences between the countryside and the city

Bl *(l – life):* deterioration of soil microbiological properties: the decline of total numbers and diversity of microorganism species, as a consequence of the increasing use of highly concentrated mineral fertilizers, irrigation, monocropping, and intensive exploitation

Bp *(p – pests):* increased incidence of invasive diseases and pests, the decline in predators' quantity, and thus the possibility of biological control of plant diseases and pests. These phenomena are being increasingly linked to the introduction through sowing and planting new plant species and cultivars, and the introduction of animal species and breeds. In addition, global warming leads to the movement of certain diseases and pests from warmer to cooler regions and higher altitudes.

Hydrological degradation (H), associated with water which is the key to life on and in the ground. Soil moisture, surface, and groundwater conditions have a direct impact on the soil as a medium for plant growth and development. Water conditions and forms on and in the soil can be represented in many ways such as:

Ha *(a – aridification):* aridification or decrease of average soil moisture content, as a consequence of reduced rainfall and soil retention properties due to loss of organic matter and deterioration of soil structure

Hg *(g - groundwater/aquifer level):* change in groundwater/aquifer level, where overexploitation of water for different purposes results in the lowering of groundwater table and accumulations. The increase of groundwater table in karstic conditions results in clogged sinkholes and large-scale flooding in karstic fields. In arid conditions, the capillary rise of water from sub-surface to surface layers can lead to acute salinization of soil and further degradation processes.

Hs *(s – surface water):* change in the quantity of surface water: change of the flow regime in the form of flood, peak flow, low flow, drying up of rivers and lakes, etc.

Hp *(p – pollution):* the decline of surface water quality due to increased amount of sediments and potential pollutants, which can lead to soil pollution or other direct or indirect effects on the quality of agricultural products, groundwater and surface water, wells and other sources of pollution

Hq *(q - groundwater quality):* the decline of groundwater quality is a direct consequence of surface water quality and human activities on the land surface. Aquifer pollution is caused by the infiltration of pollutants dissolved in surface waters. Groundwater is of great importance for human life as aquifer supplies the population with drinking water, to a large extent, but groundwater is also used for irrigation and industry. Certainly, most of the pollutants end up in seas and lakes, being the largest surface water recipients. Nitrate forms of nitrogen and phosphates are of particular concern as they have a direct impact on the eutrophication of surface water on land.

Hw *(w - wetland areas):* Reduction of the buffering capacity of wetland areas to reduce retention ability of wetlands to mitigate the flooding effects and sudden influx of water after intense and prolonged rainfall. Due to erosion processes and as a consequence of deforestation and other human activities, wetlands get backfilled with sediments in the form of silt that consequently results in their shallowing.

Along with sediments, pollutants get to the wetland, which has a direct impact on the health and life of the wetlands. Wetlands are generally considered one of the most important biodiversity reserves, and those major ones are protected under the Ramsar Convention on Wetlands. In Bosnia and Herzegovina, three habitats are protected by the Ramsar Convention: Hutovo Blato Nature Park, Bardača site, and Livanjsko field.

1.3. CHALLENGES OF IMPLEMENTING THE 2030 AGENDA

At the Summit on Sustainable Development, held on 25 September 2015 in Paris, all member countries of the United Nations adopted the 2030 Sustainable Development Agenda (Agenda 2030). Agenda 2030 contains 17 Goals of sustainable development aimed at eradicating poverty, combating inequality, and addressing climate change issues by 2030. The sustainable development goals address the global challenges we face. Land can play an important role in accelerating the process of achieving many SDGs, as well as in combating climate change, securing biodiversity and maintaining key services of ecosystems. The basic content of all 17 SDGs[2] is given below:

Even though the number of people living in extreme poverty is nearly halved - from 1.9 billion in 1990 to 836 million in 2015 – the number of those struggling to meet the most basic human needs remains overwhelming. The sustainable development goals represent a commitment, boldly undertaken, to finish what we have started and end poverty in all forms and dimensions by 2030. This involves assistance to people living in vulnerable environments, the existence of basic livelihoods, and assistance to communities affected by conflicts, natural disasters, and climate-related disasters.

[2] Downloaded and adapted: http://www.ba.undp.org/content/bosnia_and_herzegovina/bs/home/post-2015/sdg-overview.html

The aim of the Sustainable Development Goals is to eradicate all forms of hunger and malnutrition by 2030, making sure all people – especially children and most vulnerable categories – have access to sufficient and good quality food all year around. This involves promoting sustainable agricultural practices in the form of improving the living standard and capacities of small-scale farmers, providing free access to land, technologies and markets. This effort requires international cooperation, which will ensure investment in infrastructure and technology to improve agricultural productivity.

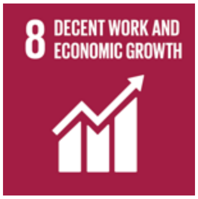
Under Sustainable Development Goal 3, the commitment to eradicate the epidemics of AIDS, tuberculosis, malaria and other infectious diseases by 2030 has been boldly undertaken. The aim is to achieve universal health coverage and provide access to safe and effective medicines and vaccines. Supporting research and development for vaccines is an essential part of the process, along with supplying affordable medicines.

Achieving inclusive and quality education for all reaffirms the belief that education is one of the most powerful and proven vehicles for sustainable development. According to this Goal, all girls and boys will complete free primary and secondary schooling by 2030. It also aims to provide equal access to affordable vocational training, to eliminate gender and wealth disparities and achieve universal access to a quality higher education.

The aim of SDG 5., gender equality, is to eliminate discrimination against women and girls everywhere. In some regions, there are still huge inequalities in terms of paid labor and labor market between men and women. Sexual violence and exploitation, the unequal division of unpaid care and domestic work, and discrimination in public office, all remain huge barriers to gender equality.

Universal access to quality and affordable drinking water by 2030. This implies and calls for investments in the adequate water supply infrastructure, sanitary facilities and improvement of hygiene at all levels. Protecting and restoring water-related ecosystems such as forests, mountains, wetlands and rivers are essential if we are to mitigate water scarcity and maintain its quality. More international cooperation is also needed to encourage water efficiency and support treatment technologies in developing countries.

Ensuring universal access to affordable electricity by 2030 means investing in clean and renewable energy sources such as solar, wind and thermal. Adopting cost-effective standards for a wider range of technologies it is possible to reduce the global electricity consumption by buildings and industry by 14%. This means avoiding roughly 1,300 mid-size power plants. Expanding infrastructure and upgrading technology to provide clean energy in all developing countries should be a crucial goal that can both encourage growth and help the environment.



The Sustainable Development Goals aim to promote economic growth through higher productivity and technological innovations. Promoting policies that encourage entrepreneurship and job creation are key to this, as are effective measures to eradicate forced labor, slavery and human trafficking. With these targets in mind, the goal is to achieve full and productive employment, and decent work, for all men and women by 2030.

Technological progress is also key to finding lasting solutions to both economic and environmental challenges, such as providing new jobs and promoting energy efficiency. Promoting sustainable industries and investing in scientific research and innovation represent an important precondition for promoting sustainable growth. More than 4 billion people still have no access to the Internet, and 90% of them are from developing countries. Bridging this digital gap is crucial to ensure equal access to information and knowledge, which in return fosters innovation and entrepreneurship.

Income inequality is a global problem that requires global solutions. This involves improving the regulation and monitoring of financial markets and institutions, encouraging development assistance and foreign direct investments to regions where the need is greatest. Facilitating the safe migration and mobility of people is also key to bridging the widening divide.

More than half of the world's population now lives in urban areas. By 2050, this figure will have risen to 6.5 billion, or two-thirds of all humanity. Sustainable development cannot be achieved without significantly transforming the way we build and manage urban space. Extreme poverty is often concentrated in urban spaces, and national and city governments struggle to accommodate the growing population in these areas. Making cities safe and sustainable means ensuring access to safe and affordable housing, and upgrading slum settlements. It also involves investment in public transport, creating more green public spaces, improving urban planning and management in a way that is both participatory and inclusive.

The efficient management of our shared natural resources, and the way we dispose of toxic waste and pollutants, are important targets for achieving this goal. Encouraging industries, businesses and consumers to recycle and reduce waste is equally important, as is supporting developing countries to move towards more sustainable patterns of consumption by 2030. A large share of the world population is still consuming far too little to meet even their basic needs. Having the per capita of global food waste at the retailer and consumer levels is also important for creating more efficient production and supply chains that are adequate to the needs and demands of the population. This can help with providing a better quality of food and shift us towards a more resource-efficient economy.

Strengthening the ecosystems' resilience and capacity for adaptation of vulnerable areas such as land-locked and island countries must be consistent with efforts to increase awareness and integrate measures into national policies and strategies. It is still possible, with political will and a wide variety of technological measures, to limit the increase in global mean temperature to two degrees Celsius above pre-industrial levels. Achieving this goal requires urgent collective action.

Over three billion people depend on marine and coastal biodiversity for their livelihoods. However, today we are seeing 30% of the world's fish stocks overexploited, reaching below the level at which they can produce sustainable yield. Oceans also absorb about 30% of the carbon dioxide produced by humans, and we are seeing a 26% rise in ocean acidification since the beginning of the industrial revolution. Marine pollution, the majority of which comes from land-based sources, is reaching alarming levels: on average, 13,000 pieces of plastic litter are found on every square kilometer of ocean. The sustainable development goals provide a framework for sustainable management and protection of marine and coastal ecosystems from pollution coming from land, as well as addressing the impacts of ocean acidification. Enhancing conservation and the sustainable use of ocean-based resources through international law will also help mitigate some of the challenges facing our oceans. Ocean protection is one of 17 global goals constituting the 2030 Agenda for sustainable development. An integrated approach is essential to making simultaneous progress on multiple goals.

Today we are seeing an unprecedented extent of land degradation, and the loss of arable land is 30 - 35 times the historical rate. Drought and desertification are also on the rise each year, amounting to the loss of 12 million hectares, affecting poor communities worldwide. Of the 8,300 known animal breeds, 8% are extinct and 22% are at risk of extinction. The sustainable development goals aim to conserve and restore the terrestrial ecosystems such as forests, wetlands, drylands and mountains by 2020. Promoting sustainable forest *management and stopping deforestation is also vital to mitigating the effects of climate change. Urgent action must be taken to prevent the loss of natural habitats and biodiversity, which are part of our common heritage. SDG 15.3 reads „By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world". Land degradation neutrality – LDN, is a new UNCCD initiative aimed at halting the active loss of healthy land due to degradation.*

The aim of Sustainable Development Goal 16 is to significantly reduce all forms of violence and wars, and work with governments and communities to find lasting solutions to conflicts and insecurity. Strengthening the rule of law and promoting human rights is key to this process, as is reducing the flow of illicit arms. Strengthening the participation of developing countries and their presence in the institutions of global governance appears to be a necessity.

Sustainable management goals can only be realized with a strong commitment to global partnership and cooperation. The goals aim to enhance North-South and South-South cooperation by supporting national plans to achieve all the targets. Promoting international trade and helping developing countries increase their exports, are basic elements of achieving a rules-based universal and equitable trading system that is fair and open, and benefits all.

There are a number of challenges to achieving these goals. They are primarily reflected in the sphere of politics, which sets the main priorities and goals in each country individually. In this respect, the pressure of the international community and global awareness are still not at a level that would provide prompt action. Positive processes occur slowly and sporadically, while negative ones are accelerated and chaotic. The best example is deforestation in the Amazon basin, which assumes catastrophic proportions and most directly affects the state of climate change on Earth.

1.4. FOCUS ON LAND SUSTAINABILITY IN BOSNIA AND HERZEGOVINA

Although soil is a limited and hardly renewable natural resource, it is given very little attention, and in this respect, it significantly lags behind the public's attention that is paid to some other ecosystem elements, such as water and air, biodiversity, etc. This often raises the question: what are the causes of such an attitude towards land? The following answers appear to be logical:

- There is an opinion that we have sufficient areas of land and there is no particular need to put it under protection,
- The existence of large areas of uncultivated land, as a result of various socio-economic issues, gives the wrong impression that we have too much land in our country and that is the reason why it is not cultivated,
- Land use and land protection are included in many laws, which makes it difficult to pursue a single land policy, and provides large opportunities for multiple cases of abuse, especially in terms of changing the land use,
- Lack of services that would continuously take care of the condition of the land, its losses, and change of use,
- Lack of a single record of land use change, land losses and degradation, especially lack of political will and social awareness of the fact that the care of the land and its protection is the basis of the well-being of the entire country.

Agricultural land is a part of the land used for agricultural production. The efficient use and protection of agricultural land is one of the most important tasks of all levels of government. The Law on Agricultural Land in the Federation of Bosnia and Herzegovina (Federation of BiH Official Gazette, no. 52/98) stipulates:

„Agricultural land as a natural resource and property of general interest to the Federation and Bosnia and Herzegovina, enjoys special protection, is used for agricultural production, and cannot be used for other purposes, except in the cases and under the conditions laid down in this Law".

Arable land includes plough-fields, gardens, orchards, vineyards and meadows. Bosnia and Herzegovina, according to statistics (BHAS, 2018), has a total of about 1,843,832 hectares of agricultural land, and an overview of areas under a certain land use per capita (3.531.159 citizens according to the 2013 census) is given in the following table.

TABLE 1. *Areas under different land uses per capita in Bosnia and Herzegovina (2018)*[3]

Land use	ha	ha/per capita
Plough-fields and gardens	597,292	0.17
Orchards	95,030	0.03
Vineyards	4,529	0.0013
Meadows	444,442	0.13
Total arable land	**1,779,632**	**0.50**
Pastures	637,979	0.18
Fallow land	64,200	0.02
Total agricultural land	**1,843,832**	**0.52**

From the standpoint of productivity and land use value, the best indicator is its bonity (soil rating). Across the territory of Bosnia and Herzegovina, the three first rating categories cover an area of only 14.2%. Combined with category IV, the total area under these types of agricultural land amounts to 31%, or slightly less than 1/3 of the total area.

The available agricultural land is characterized by fragmented land, low level of regulation unsuitable for quality cultivation, low level of irrigation and drainage, mostly monocropping with disproportionate use of artificial mineral compared to natural organic fertilizers.

According to data from the Register of farms and clients (MoFTER, 2018), the number of registered farms in 2017 was 11,883, while the total reported area of agricultural land was 327,507 hectares or 2.86 hectares per farm on average. The total arable land available to these farms amounted to 279,275 hectares or 2.44 hectares per farm.

The problem of fragmented land property requires a legal framework that will allow maximum freedom in the transfer of agricultural land between owners and users, where the market will regulate the optimal size of the farm. This can only be achieved in an environment where investors will have confidence in investing, and banks will be able to mortgage the property in order to approve a loan, thus ensuring low credit interest rates.

[3] Agency for Statistics of Bosnia and Herzegovina (BHAS), 2018

Many other supporting measures need to be implemented, such as pursuing a balanced real estate tax policy, providing incentives for young people interested in farming, job opportunities in some other sector for those who are not interested in agriculture, providing social security for those who may lose land, and providing competent and professional staff in real estate and other services associated with the land.

Today, in Bosnia and Herzegovina there is a permanent reduction in the existing agricultural land areas. Namely, urbanization, industrialization, and uncontrolled expansion of cities and other settlements have caused large and permanent losses of agricultural land. The conversion of large areas of quality agricultural land to non-agricultural could significantly change if legal provisions were respected and if the awareness was raised of the importance of this natural resource in performing its primary ecological functions and the effects of land degradation.

By their nature, all individual actions under soil protection measures can be preventive and remedial. Generally speaking, the largest number of measures envisaged under soil protection can be considered as preventive ones. Exceptions are the measures of re-cultivation (remediation) of degraded land areas.

In a broader sense, all soil protection measures can be classified into three groups: legal, educational, and technical-technological.

In a legal sense, Bosnia and Herzegovina has regulated relations within the ecological complex by the Constitution, in a way that most of the responsibility lies at the entity level. In the Federation of Bosnia and Herzegovina, responsibility is partly shared with the cantons, while the Brčko District of Bosnia and Herzegovina is independent in this respect and answers to the state-level authorities. Regulations relating to land have a particular place. In relation to land use, currently there are a number of legal regulations (such as the Law on Agricultural Land, Physical Planning, the Law on Expropriation, etc.). However, when it comes to land, adverse processes take place in practice. The diversity of land-related legislation has some negative effects on its rational use. This often leads to a violation of the law, resulting in their misuse. The processes of easy conversion of agricultural land are unfortunately ongoing, so that it often happens that the most valuable land is used for non-agricultural purposes.

What are the causes of such behavior?

Two points are particularly significant: the lack of knowledge and understanding of this important natural resource in the process of education of personnel working in such jobs, and the devastating, often emphasized, so-called economic aspect of the works associated with land use change.

A disincentive to the rational use of land, especially in urbanism, is the so-called cost-effectiveness of construction. Unsuitable land and geo-technical requirements are the most common conditions dictating the choice of site. The tendency to reduce investment cost, spontaneously leads to the consumption of the best quality land, especially in the lowland areas. Spatial development is under the pressure of current needs, partial interests, and immediate economic effects.

Legal measures, by their nature, are preventive measures to protect the land, although the control of the implementation of the enacted laws, as well as the implementation of sanctioning measures for the offenders thereof, has the character of direct actions to protect the land. Inspection services should play a special role in these activities. For these services to function properly, land inspectors need to be well informed about all aspects of soil protection, and especially about the conditions when land use can be changed.

Including this issue in the education system, which should take place through all levels of education, plays a particularly important role in land protection measures. The problem of environmental protection is so complex, that one person cannot cover it. For this reason, at the university level, it could be achieved by including certain chapters from this domain in the curriculum. The organization of such educational profiles will provide the appropriate specialists capable of integrating themselves in addressing complex environmental and land protection issues in a meritorious manner.

Technical and technological measures of soil protection include measures aimed at either protecting the quality land from destruction or re-establishing agricultural and forestry production on already degraded or destructed land. The soil protection preventive technical and technological measures include those measures and actions that allow the development of quality spatial plans based on adequate maps associated with land, especially the soil rating maps, erosion maps, and socio-economic status of a given area, development plans, etc. The remedial technical-technological measures include actions that are being taken within the remediation of degraded land.

The development of spatial plans is one of the best ways to protect the land at the local level. This is considered a basic prerequisite for the systemic protection and sustainable management of land in both urban and rural areas, which should involve a whole range of experts and specialists in various fields of planning and environmental protection.

PRINCIPLES OF SUSTAINABLE LAND MANAGEMENT 2

2.1. Ecosystem Functions Of Soil

Soil functions in the ecosystem have been and still are the subject of study by many authors and scientists, especially in this century. Here, we are mentioning some of the authors and institutions who have dealt with this issue and can contribute to a better understanding of the importance of soil as a resource and component of the environment.

Soil is a basic and hardly renewable natural resource. Together with water, air and organisms, it constitutes the ecosystem. Because of its unique characteristics, the land is a key factor of sustainability, possibility and quality of life in social development (Várallyay, 2015).

When it comes to land, there are two major concerns: ensuring sufficient food supply and functioning of terrestrial systems (Vogel *et al.*, 2018). This is especially important due to the projection of the world's population to 11 billion people by 2100 (UN, 2019). An increase in population implies the need to increase food production, and according to the FAO, by 2050 this increase should be 60% compared to the year 2005, to feed more than 9 billion people (Schulte *et al*., 2015 cited by Alexandratos and Bruinsma, 2012).

The land is used multifunctionally and its role in natural ecosystems is not an easy one. It is a dynamic system that performs numerous functions and provides the services necessary for the survival of ecosystems and human activities. Although there are numerous divisions of soil functions, they are essentially divided into environmental and technical ones.

According to Resulović (2002), the environmental function of soil is the rooting of plants and their supply with nutrients, water and air during the period of growth and development. In addition, the soil is a habitat for many microorganisms (micro, mezzo and macro pedo-fauna), some of which spend their entire life cycle in the soil, and some in the stage of reproduction or at certain periods of the year.

From the viewpoint of agricultural production, soil fertility and productivity are largely dependent on its buffering and filtering properties, adsorption capacity, oxidation and reduction potential and transformation properties, based on which particular soils are rated as suitable for agricultural production and biomass production in general.

Technical functions of the soil support roles outside the sphere of ecological functions, i.e. for the construction of settlements, industry, roads, water reservoirs, mineral exploitation, disposal of various types of waste, etc.

On the other hand, Blum (2005) divides soil functions into two groups: ecological and non-ecological. According to this author, ecological functions are reflected in the production of biomass to support the survival of humans and animals, preservation of the land environment and genetic potential habitats, while non-ecological functions are the physical basis for human activities, source of raw materials and geological and cultural heritage.

Sustainable land use implies the need to reconcile the use of the aforementioned soil functions in space and time while minimizing adverse uses such as permanent soil losses in the area of infrastructure and housing, reducing damage caused by mining and exploitation of minerals, erosion processes and sedimentation, acidification and base leaching, contamination or pollution with organic and mineral pollutants.

Soil functions are elaborated in detail within the FAO and are shown in Figure 1. Eleven soil functions are listed here, and all of them can be roughly classified as ecological and technical, with land being considered an important part of cultural heritage.

The EU Land Framework Directive (proposed in 2006, withdrawn in 2014), that is aimed, among other things, at ensuring soil protection based on the principles of preserving its functions in the ecosystem, states its importance as follows:

- Biomass production, including agriculture and forestry;
- Storage, filtering and transformation of nutrients, ingredients and water;
- Biodiversity reserves such as habitats, species and carrier of genetic potential;
- Physical and cultural environment for humans and their activities;
- Source of raw materials;

- Carbon habitat and the medium of its sequestration;
- Archive of geological and archaeological heritage.

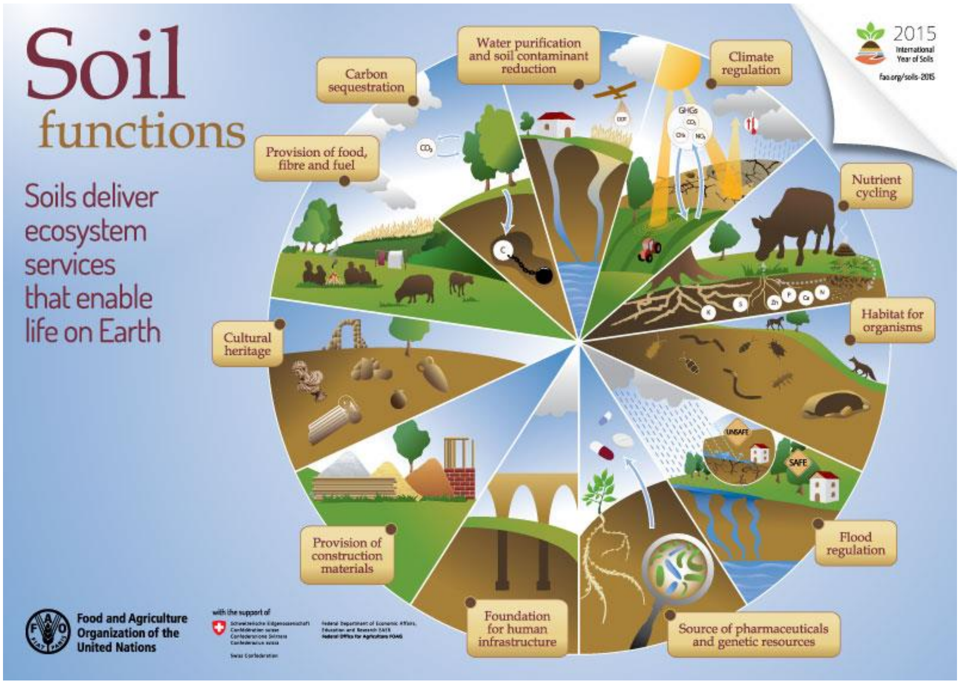


FIGURE 1. *Soil functions (FAO, 2015)*[4]

Although there are many different divisions, Breure *et al*. (2012) cited by JRC (2016), point out that soil functions are often not recognized, generally not understood, and are therefore not incorporated into ecosystem frameworks, nor is there a link between the natural asset of soil and its services. Soils may perform different functions, but some of them are better in providing certain selective functions (Schulte *et al*., 2015).

Soil degradation is a daily occurrence that impairs its functions and ability to provide services within an ecosystem, whether natural or anthropogenic. While degradation can be considered a rapid process, soil formation and its restoration are very slow processes.

[4] http://www.fao.org/resources/infographics/infographics-details/en/c/284478/

A matrix showing the impact of major processes on the potential of specific soil functions is provided in Table 2.

TABLE 2. *Matrix showing the impact of major land processes (groups of land cover flows) on the potential of specific soil functions* [5]

ES Category	**Provisioning**					**Regulating and maintenance**					**Cultural**	
Supply	Biomass production arable land	Biomass production grassland	Biomass production forest land	Raw material provision organic material	Raw material provision construction material	Storing substances	Filtering substances	Storing water	Soil organic carbon pool	Soil biodiversity pool	Platform for human activities	Storing geological/archaeologica l heritage
Urban expansion				**	**							
Agricultural intensification	*	*	*	**	**							
Agricultural extensification				**	**							
Agricultural expansion				**	**							
Forest expansion				**	**							
Water bodies expansion					**							
Forest feelings	***	***	***	**	**							

Impact

predominantly negative | predominantly positive | neutral/unclear

* Productivity is mainly supported by the use of physical assets (fertilizers, irrigation, etc.) rather than the natural potential of soils.

** In the reverse direction, the impact of extracting peat, sand, and gravel strongly depends on aftercare.

*** Forest felling's and subsequent regeneration favor biomass production on forest land in the first 20-30 years of the (70-100 year) cycle.

It can be generally said that countries are less concerned with land protection policy and monitoring of the land resources situation than with water and air protection. In this regard, the system of land monitoring is not fully developed even in the world's most developed countries.

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[5] Gregor, M., Löhnertz, M., Schröder, C., Aksoy, E., Prokop, G., Louwagie, G. 2018. Land cover changes and soil functions. An approach for integrated accounting. European Topic Centre on Urban, Land and Soil Systems (ETC-ULS).

In the last ten years, at the global level and within the UNCCD, an LDN concept has been developed to become part of the SDG goals adopted in 2015 in Paris. SDGs include goals related to soil quality from the standpoint of contamination, chemicals, and waste management.

Control of soil functions, as pointed out by Várallyay (2010; 2015), requires appropriate data: accurate, credible, identifiable (preferably measured) and precise quantitative spatial data represented in the way soil properties are well defined in terms of its characteristics, processes on and in soil, biogeochemical circulation, and current and/or potential impacts of human activities on the soil.

When it comes to monitoring indicators of the state, within the EEA – European Environment Agency, individual indicators have been designed to provide answers to key questions regarding land policy in order to support environmental policy decisions at the EU level.

The indicators are classified into five groups and should answer the following questions:

- Descriptive indicators (Type A) that answer the question: What is going on?
- Performance indicators (Type B): Is it important? Are we achieving our goals?
- Efficiency indicators (Type C): Is the condition improving?
- Policy and measures efficiency indicators (Type D): Are the measures working?
- Overall well-being indicators (Type E): Is the overall situation better for the life of humans and animals?

The EEA provides these estimates based on several key CSIs (*Core set of indicators*). Estimates are made based on the land and soil use within the LSI (*Land and Soil Indicators*) thematic cluster, which includes the following indicators: land conversion, soil imperviousness, and imperviousness change, management of contaminated sites, soil moisture status, soil erosion and soil organic carbon content.

Indicators for land fragmentation (subdivision) and rehabilitation or remediation of the soil condition are also planned.

2.1.1. Analysis Of Land Indicators In Bosnia And Herzegovina

Since 2000, land cover monitoring for the territory of Bosnia and Herzegovina has been performed regularly, every six years. The first status of coverage for EEA purposes, within the project CORINE[6] Land Cover (CLC), was developed by the Geodetic Institute of Bosnia and Herzegovina, while the other three CLC analyzes of land cover change in 2006, 2012, and 2018 were made at the Faculty of Agriculture and Food Sciences, University of Sarajevo (Čustović *et al*., 2006; 2012; 2018).

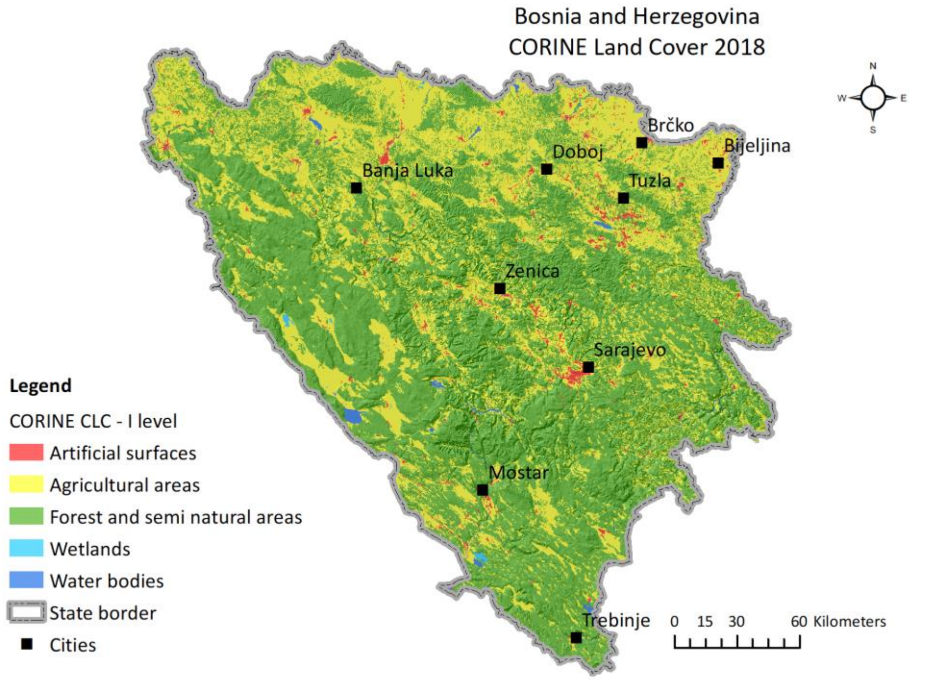
Very interesting results of dynamic character were obtained for the past nearly twenty years. They indicate the dynamism of changes in space caused by human activity or the abandonment of space by humans and animals. The war has had and still has a huge effect on changes in space, both rural and urban. Ever bigger areas are overgrown with invasive weeds and forest vegetation on abandoned farmland and pastures. The prevailing monocropping, which has an aggressive and residence character, suppresses the valuable biodiversity established by human activity in rural areas. On the other hand, growing areas, especially of agricultural land in the immediate vicinity of settlements and cities, are permanently disappearing under the infrastructure and buildings. The unplanned deforestation and devastation within this ecosystem are the facts that are understood but are not the subject of this book.

Although CORINE methodological approach is tailored to the EU needs, knowing that it is made at a small scale (M 1:100000), it is yet a piece of useful information not only for the EU but for each individual country, especially in terms of permanent land losses and change of use that converts land from one category to another. The CORINE classification has 44 classes within five major groups: artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, and water bodies.

[6] Coordination of Information on the Environment

Examples of Indicators for Bosnia and Herzegovina

Indicator: *Land conversion - CSI 014/LSI 001 - Land take*



Source: EEA, Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 2. *Land cover in Bosnia and Herzegovina in 2018*

According to the CLC, a predominant category in Bosnia and Herzegovina is the category of forest and semi-natural areas (64.4%), followed by the category of agricultural areas (33.1%). The remaining area of 2.4% belongs to the categories of artificial surfaces (1.7%), water bodies (0.7%), and wetlands (0.1%).

Land use change or land conversion has the most direct impact on its functions in the ecosystem. According to CORINE data for the period 2000 – 2018, changes in land cover in Bosnia and Herzegovina occurred on an area of 71,957 hectares (Ljuša and Čustović, 2019). Pressure on the land is highest in the case of the best quality agricultural land up to rating category IV (Ljuša *et al.*, 2016), while the expansion of disconnected urban areas on agricultural land in the period 2000 – 2012 was identified in 71 municipalities in Bosnia and Herzegovina (Ljuša, 2015). In the period 2012 – 2018, conversion of agricultural into construction land amounted to 2,107 hectares or 94% of the total conversion amounting to 2,242 hectares (Table 3.)

TABLE 3. *CORINE level I. changes in the period 2012-2018*[7]

CORINE – categories of land cover of level I	CLC2018	CLC2012	Change (ha)
Artificial surfaces	86,810	84,568	2,242
Agricultural areas	1,697,504	1,699,886	-2,382
Forest and seminatural areas	3,296,254	3,296,250	4
Wetlands	5,971	5,971	0
Water bodies	34,363	34,227	136
Total	**5,120,902**	**5,120,902**	**0**

Indicator: *Built-up - covered areas and changes within the built-up areas – LSI 002 - Imperviousness and imperviousness change*

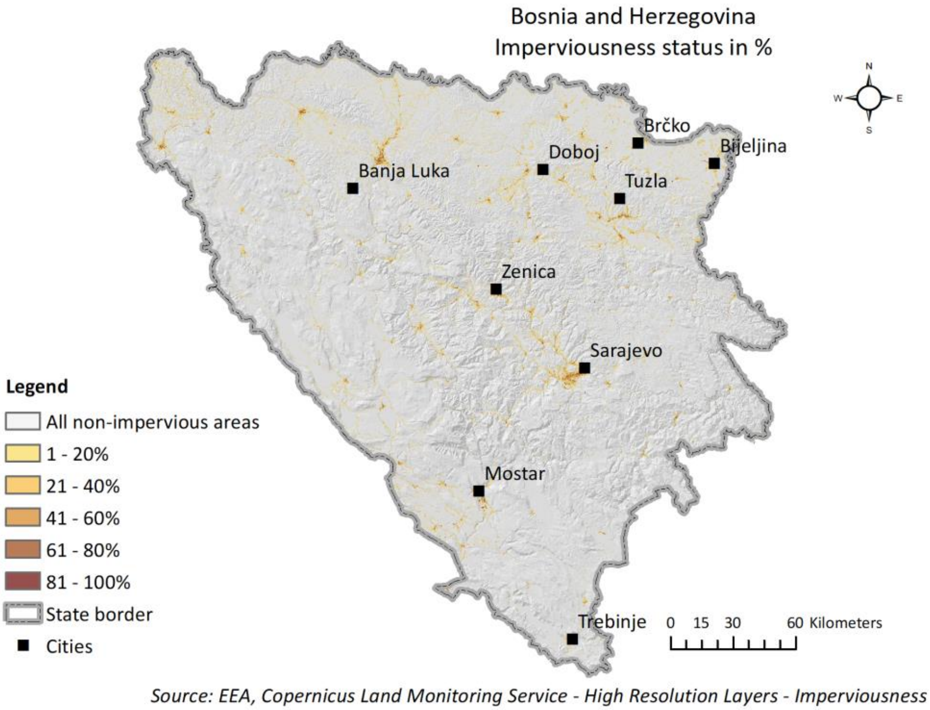


FIGURE 3. *Built-up – covered areas in Bosnia and Herzegovina in 2015*

The agricultural and forestland areas in Bosnia and Herzegovina in 2015 amounted to 4,848,422 hectares, while other categories occupied 272,481 hectares or 5.3% of the total land area.

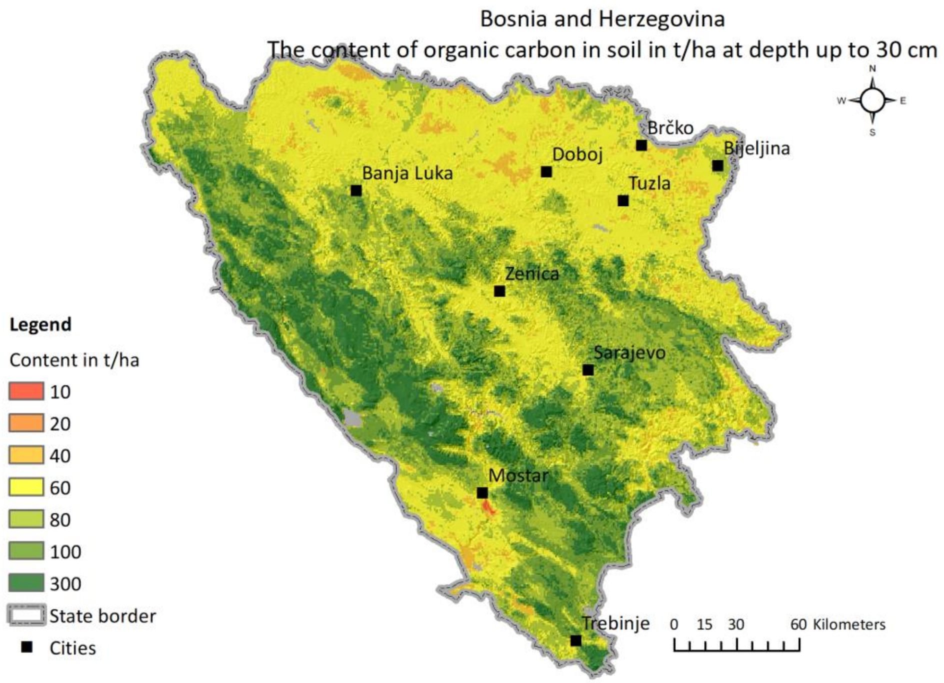
[7] EEA, Faculty of Agriculture and Food Sciences, University of Sarajevo

Changes within other land categories indicate an intensification of the use of land in these areas, especially when it comes to the increase of artificial surfaces due to urbanization and industrial development, as well as the related development of road infrastructure, which may have further significant implications for biodiversity, soil functions, hydrology, provision of ecosystem services, and nature protection (EEA, 2017).

TABLE 4. *Changes within built-up land (artificial surfaces) in the period 2012 - 2015*[8]

Category	Area (ha)
Unchanged areas (IMD=0%)	5,032,438
New cover	832
Unchanged areas (IMD>0% for both reference dates)	87,613
IMD Increase	18
IMD decrease	2
Total	**5,120,902**

Indicator: *Soil organic carbon content – LSI 005 – Soil organic carbon*



Source: Hamid Custovic, Melisa Ljusa-Faculty of Agricultural and Food Sciences University of Sarajevo, FAO GCP

FIGURE 4. *Soil organic carbon (t/ha)*

[8] EEA, Copernicus Land Monitoring Service - HRL – Imperviousness

According to preliminary research (Čustović and Ljuša, 2019) made in cooperation with the FAO GSP, and based on the data from the Soil Map of Bosnia and Herzegovina, M 1:50.000, developed by the Federal Agropedological Institute in Sarajevo, in terms of soil carbon content, the entire territory of Bosnia and Herzegovina is classified into seven categories (Figure 4.).

The category representing carbon stock in the amount of 50 - 110 t/ha consists of soils of medium stability of structure, fertility, and water retention capacity. This category is predominant in the areas of most intensive agricultural production. The class representing carbon stock above 110 t/ha consists of soils with stable structure, fertility, and water retention capacity are found in hilly-mountainous areas of forests and pastures. Other areas are moderately rich in carbon and are typical of slight slopes, North and Northeast exposure, less intensively used areas, meadows, and the like. However, it should be noted that the carbon content assessment applies to the soil depth of up to 30 cm, without the skeleton, given that such soils are rare in the hilly-mountainous region of the Dinarides, and this is the cause of errors which will hopefully be corrected in the future work on these issues.

2.2. Causes Of Land Degradation

The term land degradation refers to various forms of damage/deterioration of land and impairment of its ecosystem functions. Land resources are under increasing pressure in almost all countries due to a multitude of various factors, including i) increasing food demand, both in terms of quantity (kilojoules of energy) and quality (share of animal protein in the diet); ii) competition for arable land with bio-fuel, infrastructure development, urban expansion and purposes other than food production; iii) reduced yields and productivity in crop production due to reduced potential soil energy, its health status and other degradation processes; iv) natural factors which significantly affect the condition and potential of the land, such as climate variability and extreme weather occurrences manifested as floods and droughts.

The key drivers leading to land degradation in Bosnia and Herzegovina are numerous, and according to Čustović and Ljuša (2018), the following stand out:

- Slow adaptation and introduction of new and modern agricultural systems, and still present the use of bad agricultural practices that result in erosion and soil pollution;

- Population migration and rural depopulation leading to increased urbanization (mostly illegal), the emergence of illegal landfills and landslides;
- Non-implementation of legal regulations and measures for land protection;
- Industrialization and expansion of areas under the mineral exploitation, and disposal sites for tailings and other waste material;
- Illegal felling leading to the occurrence of erosion and landslides;
- Obsolete industrial technologies leading to soil contamination;
- All evident climate change that reflects in extremes such as droughts and floods.

Land degradation can be systematized in many ways, but in Bosnia and Herzegovina it is usually classified into three forms of degradation:

1. Land loss – temporary or permanent,
2. Reduced scope of land ecological functions,
3. Land pollution.

However, according to OECD - Organization for Economic Cooperation and Development (1994), two types of land degradation are distinguished:

1. Processes causing land quantity losses,
2. Processes causing land quality losses.

When it comes to the causes of different forms of land deterioration and degradation, they can be systematized and classified into four basic groups.

In the first group are the soils with inherited natural properties, subject to natural degradation in time and space, within the given geological, geomorphological and climatic conditions. According to Korunović (1986), all natural soils can be divided into two groups: normal soils and those requiring remediation. Normal soils in former Yugoslavia are only chernozems and eutric cambisols, and their sustainable management involves only maintaining the existing properties. Unfortunately, in Bosnia and Herzegovina, there is no chernozem, therefore eutric brown soil can be considered as the best quality soil.

Most soil types require certain minor or major remediation. For example:

i) Undeveloped soils – (fluvisols, colluviums, arenosols, regosols, and lithosols), should be primarily protected against flooding (fluvisols) and erosion by wind and water;

ii) Shallow soils – (rendzinas, rankers, brown soils on the underlying limestone, black soil, red soil), also need protection against erosion by water, as well as excessive exploitation and grazing;

iii) Soils of heavy mechanical composition and poor physical properties– (smonitza/vertisol, wetland black soil (humogley), pelosol (clay soil)), in which sustainable management involves the implementation of agro – ameliorative measures of deep loosening, flood control, basic soil drainage, etc.;

iv) Soils with excessive amounts of water – (wetland soils and alluvial deposits, pseudogleys, mineral wetland soils, etc.) require hydromelioration by means of complex flood protection measures, basic drainage, comprehensive drainage, application of agro-technical measures of deep loosening and insertion of large amounts of organic matter in order to provide structuring and water permeability;

v) Alkaline soils – (solonchak - salic and solonec- sodic soil), in which the possibility of sustainable management involves the prevention of secondary salinization and alkalization, by implementing pedomeliorative measures of gypsum treatment and removal of surplus easily soluble salts by leaching into deeper soil layers (over irrigation);

vi) Acidic soils – (podzols, lesivated soils, pseudogley, distric brown soils) required the implementation of pedomeliorative measures of calcification with humization.

In the total agricultural land area in Bosnia and Herzegovina, predominant is the share of automorphic soils (with the normal wetting regime) accounting for 2,304,843 hectares or 87.1%, while the share of hydromorphic soils (under the influence of excessive wetting) covers an area of 343,384 hectares or 12.9%. Within the share of hydromorphic soils, peatlands cover about 13,240 hectares or 0.5%, and karst fields about 80,000 hectares or 3.0% of the total agricultural land area. Of the total agricultural land, the share of shallow soils is significant and amounts to 262,155 hectares (9.9%), and acidic ones to about 945,248 hectares (35.7%).

The second group consists of soils that are damaged because of agricultural use and practices that were not at the required level, for whatever reason. It is an indisputable fact that conventional agriculture has caused many environmental disturbances. This primarily refers to the damage or disappearance of natural biotopes and landscape elements, the withdrawal and disappearance of wild game, the reduction of plant species, and water pollution by nitrates and pesticides. Anthropogenic soils have changed and are still changing thanks to a specific pedogenetic process caused by human activity i.e. anthropogenization.

Anthropogenization can be positive and negative, meaning that it can have degradation or progradation character. Positive anthropogenization increases the production properties of the soil, which is the goal of all good SLM practices.

Increasing attention is being paid to soil pollution by harmful substances. The sources of soil pollution can be various: from intensive farming, industry, municipal waste, traffic, floodwaters, sedimentation of various airborne matters (SO_2), radioactive matters getting into the soil by radiation or as a result of accidents occurring in the industry, transport, storage facilities, etc. Two terms are currently in use: „soil contamination“ and „soil pollution“. Soil contamination refers to the content of pollutants/contaminants/harmful substances in soil that is above the limit of their permitted presence in the soil (limit value), i.e. when present in the amounts threatening the safe food production and human and animal health. The term soil pollution refers to the content of a pollutant in soil that has not yet reached the limit value that threatens human health and safe food production.

Various harmful substances, as well as microorganisms that are found in the soil or have contaminated it in various ways, can indirectly get into a human body as well. For example, mercury, lead, cadmium that are normally absorbed in large amounts by some herbaceous plants (cabbage, spinach, kale, etc.), may subsequently get into the human body through the food chain. Because of the lack of knowledge about the state of pollutants in agricultural soils, we can also say that we do not know what is the quality of food we eat in terms of the presence of certain harmful substances in it. This awareness of the presence of pollutants in agricultural soils is of particular importance, especially from the aspect of food safety and human health.

One of the most important factors of agricultural land degradation in Bosnia and Herzegovina is agricultural production itself, which will be further elaborated as it is closely related to the topic of SLM in agriculture.

The third group of damage includes soils that are used outside the sphere of agriculture and forestry, mostly for infrastructure, settlements, and exploitation of mineral resources. Land losses or change of use of natural land, by duration, can be divided into two basic groups, leading to i) temporary exclusion of land from the primary sphere or temporary losses, ii) permanent exclusion of land from production or permanent land losses.

As stated earlier, Bosnia and Herzegovina does not have enough quality land. Even so, land use requirements for other purposes (technical soil functions) beyond its primary function, i.e. ecological or biomass production in agriculture and forestry, are constantly increasing.

According to the analyzes by Ljuša and Čustović (2019) based on the CORINE data, during the period 2000-2018, agricultural areas were reduced by 14,152 hectares, with the largest decrease of 9,326 hectares occurring in the period 2000 - 2006.

In the context of the conversion of agricultural land to artificial surfaces, the largest increase occurred in the class of discontinuous urban fabric - by 6,099.4 hectares, with 98.3% of these changes occurring in the period 2000 - 2006. Industrial and commercial units also increased at the expense of agricultural land - by 340.59 hectares (2000 - 2006), 146.61 hectares (2006 - 2012), and 78.6 hectares (2012 - 2018). In the context of temporary losses, mineral exploitation sites occupying 8,072 hectares increased by 653.72 ha (2000 - 2006), 718.11 ha (2006 - 2012), and 808.6 ha (2012 - 2018).

It is also necessary to emphasize the succession processes on agricultural land, which, in the period 2000 – 2018, were identified on an area of 2,590 ha, of which 853.79 ha on pastures, noting that CORINE is limited in identifying abandoned areas due to map scales.

However, temporary and permanent losses were identified in forestland as well, though to a much smaller extent.

The question is – can increasing demands for the use of land for technical purposes be stopped? It should be immediately pointed out that there are no absolute measures in preventing land losses.

There will continue to be tendencies for using land outside the agriculture and forestry spheres, linked to an increase in energy requirements as well as many other goods, which is ultimately linked to population growth.

Bosnia and Herzegovina is also characterized by the fourth group of damage, where the land damage occurred as a result of the 1992 – 1995 war. Significant areas of agricultural and forestland are contaminated with mines, therefore they cannot be normally used for human and animal needs.

According to estimates by the Bosnia and Herzegovina Mine Action Center (BHMAC) (2019), the current size of a suspected mine contaminated land area in Bosnia and Herzegovina is 1,018 km^2 or 2.1% of the total area, scattered in 8,525 suspected micro-locations, and affecting 545,603 inhabitants or 15% of the total population. The presence of such a large number of mines, which in addition to threatening human lives, prevents the use of land areas for agricultural production as well as for the exploitation of wood in forestry. The demining process is very slow and requires considerable financial resources. Demining of 1 m^2 of land cost 5 KM (2.5 EUR). If continued at this rate, it is estimated that the entire territory of Bosnia and Herzegovina will be demined in approximately 20 – 30 years.

2.2.1. Impact Of Agriculture On Land Degradation And The Environment

Agriculture, being one of the essential economic activities and economic development of any country, has a great influence on land processes and various types of its destruction and degradation. Environmental pollution caused by agricultural activities is currently a topic of concern not only to many experts but also to the general public, especially in areas having issues with increased concentrations ofnitrates, phosphates, pesticide residues and other pollutants in drinking water and soil, which often brings into question the quality of certain agricultural products. In agricultural land, protection and preventive actions are related to the preservation of its physical and chemical properties, and particularly to the stability and character of its structure.

The structure of agricultural land can be seriously deteriorated by compaction, which can be induced in various ways. Most often it is the use of heavy agricultural machinery, poor tillage especially if performed during periods of bad weather conditions and rainfall (excessively wet soil should not be tilled). The soil structure can also be disturbed by the improper application of mineral and organic fertilizers.

For example, high doses of low-quality mineral fertilizers, their poor chemical composition, etc., can have an adverse impact not only on soil structure but also on environmental pollution (contamination of soil, groundwater, waterways, rivers, lakes, seas, etc.). In addition, high doses of mineral fertilizers lead to soil depletion due to high yields (loss), especially in organic matter and calcium, which has a direct impact on the stability of the soil structure. The lack of organic matter (humus) in soil can lead not only to the deterioration of its structure but to the overall condition of its physical and chemical properties. Besides, inadequate application of organic fertilizers (high doses, poor quality raw manure, and poor application methods, etc.) can also lead to secondary effects such as soil pollution and invasion of weeds, leaching of waste materials, especially nitrate and ammonium forms into groundwaters, surface watercourses, rivers, lakes, and seas. These pollutions and contaminations are primarily related to nitrates, but also soil contamination with heavy metals. Soil contamination is part of general environmental pollution and should therefore be treated as such.

The main soil pollutants are primarily agrochemicals (fertilizers and pesticides). In the lowland areas of Posavina, in river valleys on alluvial deposits, and in karst fields where intensive production of crops, vegetable, and fruit is carried out, there is certainly a considerable uptake of pollutants into terrestrial ecosystems, being a consequence of the application of more chemicals in the form of mineral fertilizers, and in some cases, as previously noted, organic fertilizers, with the issue of nitrogen often in the first place.

Vineyards and orchards, as well as plough fields are normally situated on sloping relief surfaces and locations. In addition to pollution caused by the use of chemicals, erosion of varying intensity occurs, which further affects the removal of soil particles, and the pollution of surface watercourses. Different types of soil, as well as the amount and distribution of rainfall in certain parts of Bosnia and Herzegovina further contribute to the impact of agricultural activities on the state and quality of the environment.

Dangerous pollutants also include heavy metals (lead, cadmium, chromium, mercury, nickel, zinc, arsenic), radioactive materials, waste materials, and various types of sludge, if applied on agricultural land for multiple years. Heavy metals are becoming increasingly present in agricultural land, for all the above-stated reasons, so the question arises whether they are also present in agricultural products we consume on a daily basis.

The presence and source of heavy metals in soil can be of natural geogenic origin, but it can also be a result of the use of wastewater for irrigation; sludge as well as municipal and household waste for fertilization; and, wastewater from illegal landfills reaching agricultural land. In recent years, there is an increasing occurrence of floodwaters collecting and bringing various substances on their way from farms, settlements, industrial plants, etc., which is an additional form of land degradation and introduction of harmful substances into the soil. These occurrences of potential contamination are mostly related to lowland filed areas and watercourse valleys.

An important condition for sustainable land management is the choice and type of agricultural production in accordance with the soil properties and the climate conditions of the area. It is a prerequisite for stable economic development and environmental risk reduction. Land degradation should be avoided, and the previously degraded land should be gradually rehabilitated. Accordingly, soil fertility should be maintained or improved by choosing the appropriate cultivation method and agricultural practices for a given crop. Regular soil fertility control should be performed at least once every five years to obtain reliable data on the condition, fertility, and needs for its improvement. The priority of achieving high yields and producing good quality products is achieved by the use of organic fertilizers, and the use of manure and mineral fertilizers should meet crop requirements for nutrients with a minimum of environmental pollution. The quantities should be based on the needs of the plants and the nutrient content of the manure. The total amount of nitrogen applied to the soil must not exceed 170 kg/ha (Nitrate Directive).

The Good Agricultural Practice (GAP) Code forms the minimum standard for farm management that includes the protection of natural resources environmental management, workforce safety, animal health and welfare, food security, and health protection. The Code of Good Agricultural Practice is just a set of recommendations to help farmers improve their performance. It is normal for good agricultural practice to be supported by legislation. Implementing the Code in agricultural practice will be easy for some farmers, but in some areas, it will be difficult to implement because of the natural conditions, especially in marginalized areas. The Code requires farmers to contribute, to the best of their abilities, to the conservation of the natural environment, the conservation of soil fertility, and the maximum utilization of potential aimed at food production and the achievement of the quality of agricultural products.

2.3. Measures To Improve Productivity And Conserve Agricultural Land

In order to minimize the negative impact of agricultural activities on the condition and degradation of land, it is necessary to take a number of measures and procedures that will help preventive conservation of land, improvement of the level of degradation, or its natural potential. One of the important procedures is to know the natural properties of the soil, which is achieved through detailed pedological research and fertility studies. The identification and selection of a set of soil quality parameters that will be dynamically monitored during the monitoring and research is of particular importance.

For this purpose, it is necessary to establish a common and freely available database on land or the Map of land use value at the municipality level, and preferably at the local community level, which would be the result of pedological and soil rating studies, as well as of continuous monitoring that would be under the jurisdiction of Federation of BiH and cantonal institutions in charge of spatial planning and rural development. Such a legal basis already exists at the level of the Federation of Bosnia and Herzegovina, where the spatial planning departments are required to have the soil bonity map at the scale M 1:10000. In this regard, the strengthening of institutions that will deal with the protection, regulation, and sustainable use of agricultural land is needed.

At the cantonal level, there are funds for this purpose that were obtained from the conversion of agricultural land into construction land and should be available to the local communities so they could use them for land regulation, rehabilitation of degraded land areas in the local community. In order for agricultural land improvement measures to be sustainable and to reduce the degradation process, it is necessary for the farmers to be educated. Farmers' knowledge must be very broad and comprehensive, with extension services and permanent education playing the key role. Continuous education of farmers on erosion and conservation measures is one of the priorities.

Protection against erosion and conservation is the farthest-reaching measures to protect the land from its further destruction and degradation.

Soil cultivation and preparation, with mandatory control of the application of adequate amounts of mineral and organic fertilizers, should be based on good practice principles with regard to soil type, crop type, and mandatory control of the content of mineral nutrients in the soil.

In view of the increasing use of pesticides, including the soil treatment with insecticides, it is necessary to introduce strict control and supervision of the use of all types of protective chemicals. A prerequisite is a good collaboration of farmers with the suppliers of protective chemicals and extension services in the field. The program to protect the most important crops during the vegetation period should be available to all farmers.

Water as a factor has a very important impact on the land condition and its degradation. The best way to control this factor is to regulate excess water on the land plot by systematic measures of drainage and by applying an adequate irrigation system in terms of standards and rounds, according to the soil water retention properties and the requirement of the crop in certain phenophases of development. Regulation of the soil water regime, both surplus and deficit, is one of the preconditions for safe and stable production. Water scarcity and the growing problem of extreme droughts and its adverse effects on land, and thus on agricultural production, as well as flooding, should be addressed through the construction of irrigation, flood control, and drainage systems, utilizing building infrastructural facilities for drainage and irrigation in the wider area, preferably at the basin level.

Developing regulations on the application of the best agricultural practices is one way to improve the processes and measures outlined above. On the other hand, the basic strategic goals of sustainable land use to be pursued need to be directed towards improving the legal framework for the protection of agricultural land and adopting the lacking regulations, as well as harmonizing the legislative documents with the EU legislation in the area of agricultural land.

Preventing further loss of agricultural land, maintaining and improving its quality within agricultural activities is one of the most important tasks of every agronomist. In this regard, specific energy should be directed towards protecting the land, not only from degradation processes but also from converting the best-rated categories of agricultural land for non-agricultural purposes, particularly for construction land, where it gets permanently lost.

2.4. Sustainable Land Management And Improvement Of Living Conditions

Numerous socio-economic and environmental benefits associated with sustainable land management, both to its direct users and community, derive from its significance for global sustainable development.

This significance has long been recognized and acknowledged at the highest international level, so the sustainable land management directly or indirectly impacts on the majority of global goals defined by the 2030 Sustainable Development Agenda of the United Nations. Moreover, the practice of sustainable land management is essential to achieving several key global goals of sustainable development.

Among them, the following sustainable development goals stand out (Akhtar - Schuster, 2017; Smith *et al*., 2018):

- Sustainable Development Goal 1. states that it is necessary to „eliminate extreme poverty worldwide".
- Goal 2. envisages the eradication of famine and the achievement of food supply, as well as improved nutrition while promoting sustainable agricultural production.
- The Sustainable Development Goal 13. calls for urgent action to be taken to combat climate change and its effects.
- The Sustainable Development Goal 15. is to protect, restore, and promote sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, stop, and reverse land degradation and stop biodiversity loss.

The majority of the extremely poor population, targeted by the first goal, live in underdeveloped or developing countries. In providing livelihoods, most of them tend to rely on land as the only available resource, focusing on some of the activities within the agricultural production. Therefore, the level of sustainable agricultural production that will be implemented will determine the content and quality of Goal 1.

The second goal of sustainable development is an even greater challenge for land management, as it involves providing enough food to eradicate hunger for the growing population on Earth by 2030. Given that land resources are limited, agricultural production on existing land areas has its biological limits. Climate change likewise additionally threatens the quantity and stability of production. To achieve this goal, we need to have enough healthy land that is managed by means of a continuous implementation and improvement of sustainable practices.

The need for urgent action to combat climate change and mitigate their effects on the life of the population places the focus on sustainable land management.

This is one of the cornerstones of the so-called „climate-smart“ agriculture. Climate-smart agriculture is an approach to agricultural production that will ensure sustainable production growth and food security in the conditions of global climate change. It also means that this approach should mitigate the effects of this change and work to increase ecosystem resilience to climate change.

The fifteenth global sustainable development goal is fully and explicitly dedicated to the sustainable management of agricultural and forest land and reflects a growing awareness of the importance of sustainable land management for achieving not only the goals of sustainable development but also the goals of numerous environmental conventions and agreements, and their synergy aimed at ecosystem sustainability. Particular emphasis has been placed on neutralizing land degradation, so many countries have accordingly incorporated in their national strategic documents the objectives relating to this important problem whose solution is one of the preconditions for the long-term meeting of ever-growing food demands while preserving ecosystems and biodiversity.

2.4.1. Benefits Of Sustainable Land Management At The Global Level

If sustainable land management measures are implemented in a planned and adequate manner, they provide numerous benefits, both for landowners implementing them on their properties and for the wider community, locally, regionally, and globally. On a global scale, the benefits of sustainable land management provide numerous and multiple benefits of social, economic, and environmental character that contribute to the overall well-being and improvement of the living condition on Earth.

The most important socio-economic benefits (adapted from the World Bank, 2008; Sanginga and Woomer, 2009) include: reducing poverty and famine; creating a favorable environment for broad and sustainable rural and any other economic growth; contributing to raising productivity and competitiveness of agricultural production; contributing to gender equality and empowerment of women in rural areas; incentive for economic growth outside agriculture, reducing the pressure on land overexploitation; managing risks and mitigating risks and vulnerabilities; articulating good practices in the area of agrarian policy and investments; combating diseases and improving general health; upgrading local knowledge on ecosystems, and; developing global partnerships.

Sustainable land management is key to a global response to climate change, land degradation and biodiversity conservation, food security challenges, and is vital to human and planetary well-being. Global environmental benefits of sustainable land management include improved provision of agricultural and forest ecosystem services; mitigation of climate change through reducing greenhouse gases emission and increasing carbon sequestration; increased resilience of agro-ecosystems and forest ecosystems to climate changes and other anthropogenic and natural stress sources; conservation and sustainable use of biodiversity in natural and production environments; reduced pollution of aquatic environments and better rehabilitation of flood-induced damages; conservation of biodiversity, reduction of extinction rate and depletion of flora and fauna.

2.4.2. Benefits Of Sustainable Land Management For Landowners

Introducing sustainable land management practices for owners who have not previously used them is a major challenge associated with a number of dilemmas and difficulties. Nonetheless, landowners will be prepared to adopt these practices if they can provide direct benefits: subsistence farming to meet their demands for food, and inputs for agricultural production such as animal feed, planting material, etc.; increase in income and profit – either by increasing the available land area or by increasing the scope of production and yield, or by introducing the new production lines, diversifying their production, and introducing new production practices. Farmers are likewise very interested in reducing production risk – by stabilizing yields and revenues, by being better prepared to respond to climate challenges and threats, i.e. by increasing revenue while reducing production and market risks.

In addition to the above, sustainable land management practices can also bring indirect benefits to landowners who are unaware of, or unable to perceive them at the time of decision making to implement these practices. These include the diversification of business activities, thus reducing dependence on agricultural production and the risks associated with it, and better use of available natural, human and financial resources, and ultimately a better standard of living and generally better living conditions.

The key role in deciding to adopt sustainable land management practices is played by the cost-benefit ratio. In determining this ratio, the short-term costs and benefits, and long-term costs and benefits are taken into account.

When it comes to costs, the short-term ones imply the initial investment cost, i.e. the cost of introducing the practice, while the long-term costs refer to the maintenance of the introduced practice in the long run. When evaluating investments in one of the sustainable land management practices, it is crucial to accurately identify all costs and benefits, knowing that some costs can sometimes be difficult to quantify. Cost-benefit ratio assessment is a complex and demanding process. Both costs and benefits are often specific to a very small locality, so there is no generally applicable pattern for their assessment.

When it comes to the dynamics of benefiting from the introduction of sustainable land management practices, different practices will show different cost/benefit dynamics. The following scenarios are possible in that regard (Liniger *et al.*, FAO, 2011):

a) Long-term benefit, with no quick payback in the short term (short-term investment) – such practices are generally unattractive to land users who do not have their own equity and are unlikely to opt for them unless there is financial support to ensure initial investment, and even if this is the case, it is necessary to provide funds for maintenance until the benefits are realized.

b) The benefit is realized in the long run, and in the short-term, the cost-benefit ratio is balanced. This scenario is also only available to those landowners who are able to finance the initial investment themselves or have financial support for the initial cost and can wait for the benefit period.

c) Land users have a quick payback, i.e. both short-term and long-term benefits. This is an ideal situation because, even if we take into account the fact that it is necessary to provide an initial investment, or some other form of assistance (micro - credits, inputs, market access support), thanks to the quick return on investment, landowners are able to repay loans in the short term.

2.4.3. Investment Challenges For Land Users

The challenges associated with the introduction of sustainable land management practices are highly case-specific and entirely dependent on the landowner's previous practice, primarily of their economic situation and financial power.

In some cases, quite a few changes to the practice are required, and thus the challenges are smaller, while in some others there is a complete change in managerial approach and practice. Such cases are also related to a greater requirement for investments as well as greater difficulties and challenges.

Market-oriented farmers with large estates and large-scale farms are in a much easier position than small farmers who are mostly involved in subsistence farming. The challenges that landowners face in relation to taking up sustainable land management practices refer to the needs for capital, organized market, labor availability and access to knowledge (adapted from Liniger *et al.*, FAO, 2011):

a) The requirement for capital is a particularly important challenge for the initial investment and sustainability of the newly taken up practice. Initial investment refers to the adoption of technology (procurement of inputs, machinery) and in most cases, it exceeds the financial capabilities of farmers, especially the poorer ones. In countries such as Bosnia and Herzegovina, where small-scale farmers represent the vast majority, this is one of the key challenges that can be overcome by simultaneous measures of appropriate land policy and the provision of favorable funding sources. Right now, there are neither land policy measures nor credit conditions that are adequate to the capabilities of landowners, especially small-scale and poor farmers.

b) The market organization essentially determines access to the necessary inputs (seeds, planting material, protection chemicals, machinery, animal feed) and the possibility of placing the product on the market, and thus the ability of landowners to sell and make a profit. In addition to the organization of distribution channels and the existence of market institutions, access to the market for procurement and sale is considerably influenced by the level of development of transport infrastructure.

c) Labor availability can be a serious constraint to the introduction of sustainable land management practices because of the poor demographic situation in rural areas, where the age structure of the population is adverse. In addition, the available workforce, including young generations, generally does not consider agriculture to be an attractive activity and rather seeks employment in activities other than agriculture.

d) Mastering the knowledge and techniques necessary for taking up sustainable land management practices involves the transfer of knowledge. Those technologies and practices that are the product of the landowners' own initiative have the best chance to succeed. The best practices are those of which the landowners have some previous knowledge and experience and are therefore easier to learn and take up. An important prerequisite for success is that landowners are offered technologies that they can easily recognize as workable, attractive, and profitable, as well as practices that will contribute to improving living conditions and standards.

The decision whether to introduce sustainable land management practices or not can also be influenced by many other factors such as: technology requirements that farmers may be unfamiliar with; resistance to measures that are not their own initiative but are perceived as „imposed“; the requirement of certain technologies to cease production; certain technologies can exacerbate some problems (emergence of weeds, pests, diseases); if technology cannot increase yields, chances are that it will not be adopted; increased risk of taking loans can also be one of the reasons for refusing to take up new technologies in practice (adapted from Hellin and Haigh, 2002).

Institutional and legal regulation of the land market, development, and transparency of land sale and lease, security of property rights, adequate legislation relating to land inheritance, are key prerequisites for both individual and collective sustainable land management. These prerequisites have not been met in Bosnia and Herzegovina.

In addition, huge population migrations caused by the war have left significant land areas in the status of abandoned property, which in the long term not only hinders sustainable land management but also threatens it with further degradation.

One of the most frequently mentioned constraints for agricultural development in Bosnia and Herzegovina is the very much-pronounced fragmentation of land property, which is most directly related to sustainable land management.

Although the Law on Land Consolidation of the Federation of Bosnia and Herzegovina was adopted in 2016, very little progress has been made in this area. Land estates are extremely fragmented, and the Law on Succession does not treat agricultural land differently from other forms of property, which leads to further fragmentation. This situation makes sustainable land management practices more difficult to implement and less economically justifiable.

2.5. CHALLENGES OF CLIMATE CHANGE AND SOIL DEGRADATION

According to the Intergovernmental Panel on Climate Change (IPCC), ecosystems are exposed to various pressures, such as changes in land use, population growth, and increasing demands for natural resources, causing huge changes in ecosystems and their increasing fragmentation.

Climate changes, as a result of natural cycles and anthropogenic impact, represent additional pressure that could permanently change or threaten the situation in many ecosystems, and affect the nature of future land use and thus its potential degradation. Threats due to climate change are global by its characteristic, with direct and indirect impacts at the regional and local levels, resulting primarily in rising air temperatures, longer and more pronounced droughts, and reduced precipitation or its stochastic spatial distribution.

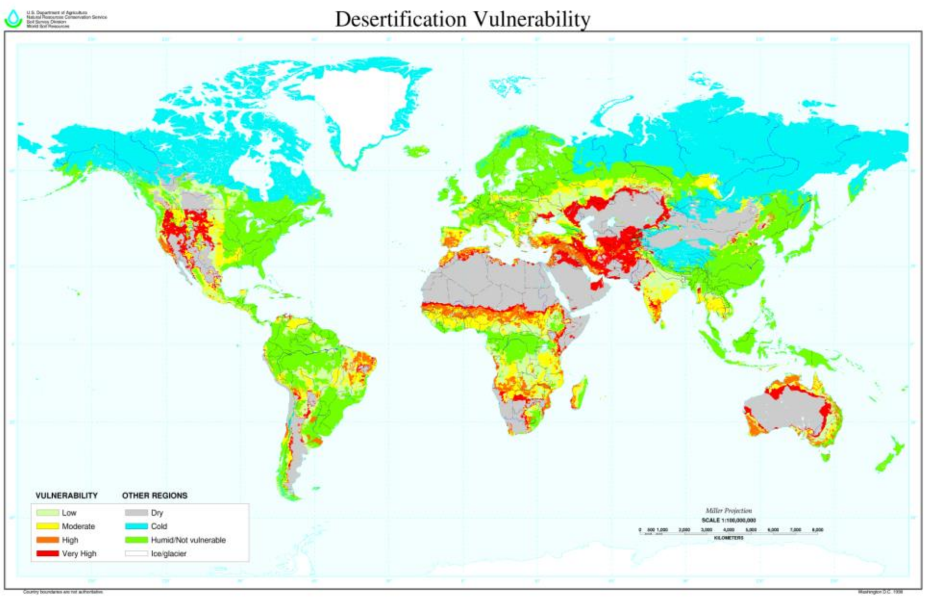


FIGURE 5. *Areas vulnerable to desertification in the world*[9]

Ecosystem vulnerability:	Low	Medium	High	Very high
Condition of the ecosystem by region:	Dry	Cold	Wet/not vulnerable	Snow/glaciers

[9] US Department of Agriculture, downloaded from Wikimedia 1998

2.5.1. Impact Of Climate Factors On Land Degradation

By definition provided by the UNCCD, climate variability is clearly recognized as one of the major factors contributing to land degradation. In determining the areas at risk of soil degradation and potential desertification, one of the most important climatic factors is precipitation. Precipitation plays an important role in the development and distribution of vegetation cover on Earth, but because of its variability and the occurrence of extremes, it can lead to the process of land degradation. The amount and annual distribution of precipitation are among the most important factors having an impact on biomass production.

In recent decades, the agricultural sector in Bosnia and Herzegovina has been facing the effects of an increasingly extreme climate, showing significant vulnerability to climate variability, which has become particularly pronounced through the increasing occurrence of droughts and floods. A variety of drought indices has been developed for monitoring, analyzing, and assessing drought worldwide.

Here, we will look at two drought indices: the Aridity Index (based on the ratio of annual precipitation and potential evapotranspiration P/PET), and drought assessment according to the Standardized Precipitation Index (SPI).

Aridity Index based on the ratio of annual precipitation and potential evapotranspiration P/PET

The Aridity Index (AI) is used in the classification of arid and semi-arid regions, as a numerical indicator of the ratio of annual precipitation and potential evapotranspiration totals (UNEP, 1992).

Arid areas exist where potential evapotranspiration (PET) is higher than precipitation. When precipitation is higher than potential evapotranspiration, it can compensate for the loss of water due to evaporation, and surplus water reserves are accumulated in the soil.

However, when the situation is reversed, precipitation cannot compensate for the water loss due to evaporation, so water reserves from the soil are consumed. If this precipitation deficit is prolonged and high, a drought occurs. Therefore, precipitation deficit is a good indicator of aridity. According to the annual levels of AI, Bosnia and Herzegovina falls within the humid areas (AI> 0.65) (Figure 6.).

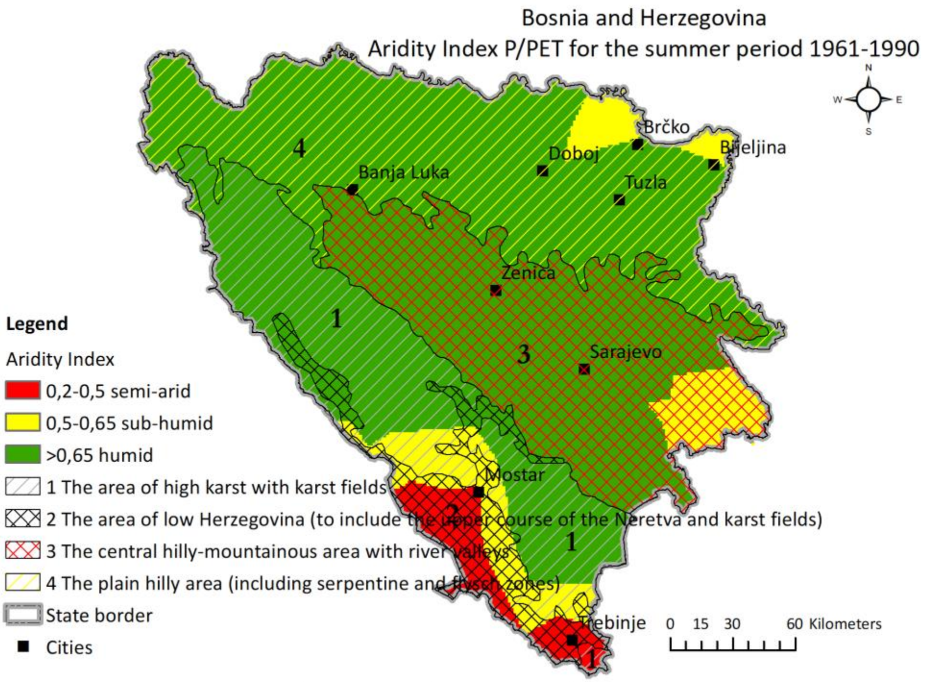


FIGURE 6. *Aridity Index for the summer period (June, July, August), 1961 - 1990*

However, if we look at the levels shown for different years and by months, we can see lower levels of the Aridity Index that are particularly pronounced in the summer months when the requirement for water is the highest. According to the levels of the Aridity Index for the summer season (June – July - August), most of the interior of Bosnia and Herzegovina has humid characteristics. The semi-arid zones are those that are most vulnerable to drought and water deficit, occupying the area of the far south, i.e. the southern sub-Mediterranean part of the country. This zone continues into the sub-humid zone that also occupies the eastern areas (Podrinje) and the northeastern part of the country (Posavina and Semberija).

Drought assessment according to the Standardized Precipitation Index (SPI) [10]

In drought assessment, the Standardized Precipitation Index (SPI) is the most widely used tool, developed to quantify precipitation deficits for different time periods (1, 2, 3, 4, 6, 12, 24 months).

[10] Source of chart in this sub-chapter: S. Hodžić, Federal Institute for Hydrometeorology

As a drought indicator, SPI recognizes the importance of timescales in the analysis of water availability and use of water resources. The nature of the SPI makes it possible to determine the incidence of drought (time of occurrence) or anomaly/deviation in the occurrence of wet periods for any location on Earth for which precipitation data are available.

As an example, we have the presentation of the SPI for a three-month timescale for the month of August (August – July - June) for the MS Sarajevo, which gives us an assessment of the moisture condition during the summer season (June – July - August). For the time series 1961 – 2017, an increased incidence of drought has been recorded, especially since the beginning of the 21st century (Chart 1.). Heavy droughts caused huge damage to agriculture in 2000, 2003, 2007, 2011, 2012, and 2016. It can be said that during the summer season, when water is most needed by the plants, the soil is highly exposed to soil water deficiency. Therefore, a successful prevention of the adverse effects of drought and soil damagesrequires providing water reserves for irrigation.

Due to the high temperatures and the risk of summer droughts, agriculture in Herzegovina and in the north of the country shows a high vulnerability to the variability of climate occurrences, be it droughts or floods. In addition to droughts, in the period 2000 – 2017, agriculture was affected by heavy rains and floods, hailstorms, high wind, frost, and heavy snowfall. The lack of precipitation is particularly pronounced during the summer months, and combined with an increase in air temperature and faster soil warming. Maximum temperatures that cause increased evapotranspiration are particularly problematic. This situation leads to an accelerated loss of soil moisture, which causes the loss of soil biodiversity and its degradation, associated with a decrease in fertility, reduced crop yields, and indirectly the risk of wildfires.

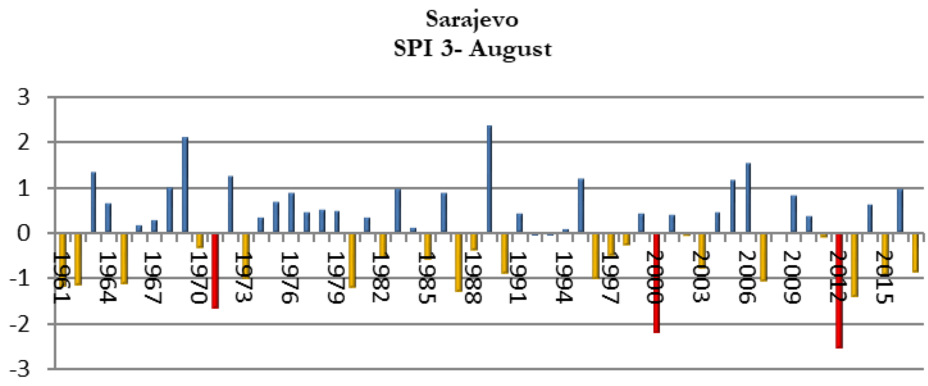


CHART 1. *Standardized Precipitation Index for Sarajevo (1961 - 2017)*

Climate change observed in Bosnia and Herzegovina

Climate change is, without doubt, one of the greatest threats to all of humanity in the 21st century, which calls for urgent action, warns the IPCC in its report (2013). The IPCC states that the climate regime as we knew it in the 1950s has already sustained numerous changes, with global warming on the one hand and the efforts of the international community to halt temperature increase at 1,5°C compared to the pre-industrial time on the other.

In the period since the 1950s to this day, many of the observed changes have been unprecedented over the past decades and centuries. The atmosphere and oceans are warming up, concentrations of greenhouse gases have increased; each of the last three decades was successively warmer on the Earth's surface than any previous decade since 1850. The average combined land and ocean surface temperature increased by approximately 0.85°C during the period between 1880 and 2012, and by 0.72°C (0.49 – 0.89°C) in the period 1951 - 2012; the amount of snow and ice is declining, leading to a constant rise in sea level. All these changes can almost certainly be attributed to human activities, especially when it comes to greenhouse gas emissions, and primarily the burning of fossil fuels, land use changes, deforestation, etc.

Evident trends in climate change, especially after the fifties of the past century, have a negative impact on all systems of invaluable importance to man and life on Earth.

It is expected that climate change in the future is likely to alter temperature and precipitation patterns, sea level, increase the frequency and severity of many types of extreme events, including floods, droughts, wildfires, storms, storm winds, etc., and affect other aspects of climate the natural environment depends on, where land as an integral part of the ecosystem cannot be excluded. The climate changes observed in Bosnia and Herzegovina are manifested primarily in the evident change in air temperature, i.e. an increase in air temperature, mean, mean maximum (Chart 2.) and mean minimum air temperature (Chart 3., all on the Sarajevo example), but also changes in the precipitation regime which impacts on the delicate balance of nature.

The analysis considers the trends and variability of annual and seasonal sequences of air temperature and precipitation in climatically different areas of Bosnia and Herzegovina for the period 1961 - 2018, and temperature indices.

An analysis of the multi-year data (1901 - 2018) shows a trend of a continuous slight increase in mean annual air temperature. The level of the annual trend ranges from 0.4 to 1.0°C, while the increase in temperature in the vegetation period (April - September) goes up to 1.0°C (Third National Communication and Second Biennial Update Report on Greenhouse Gas Emissions in Bosnia and Herzegovina, 2016). However, increases in air temperature since the beginning of the 21st century have been even more pronounced (example of the Sarajevo area, Chart 4.), where all of the years in the period 2000 – 2015, except 2005., are among the ten hottest since the beginning of meteorological measurements.

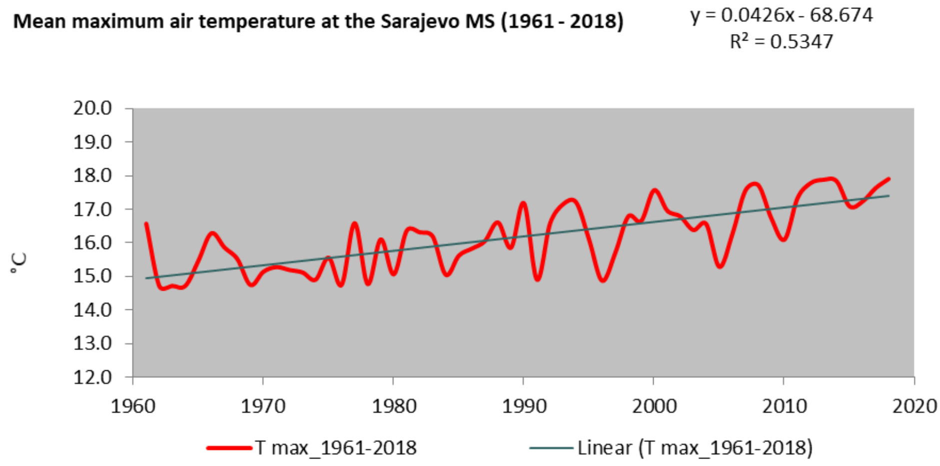


CHART 2. *Mean maximum air temperature at the Sarajevo MS (1961 - 2018)*

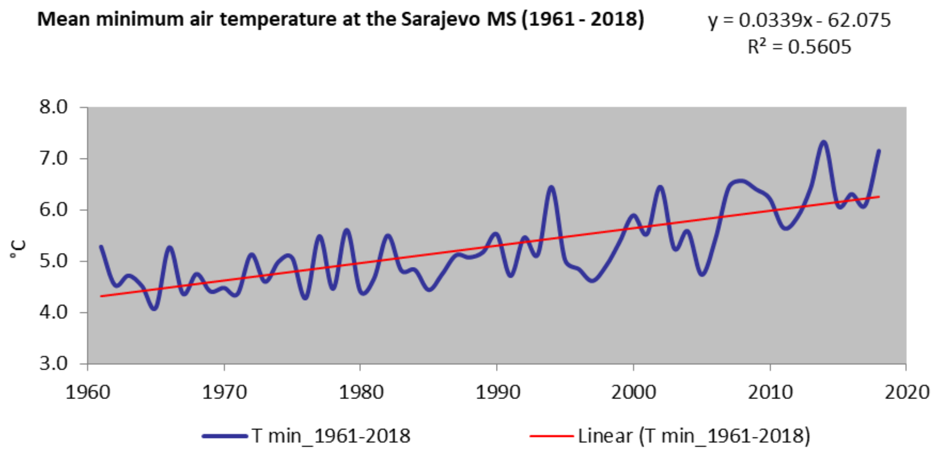


CHART 3. *Mean minimum air temperature at the Sarajevo MS (1961 - 2018)*

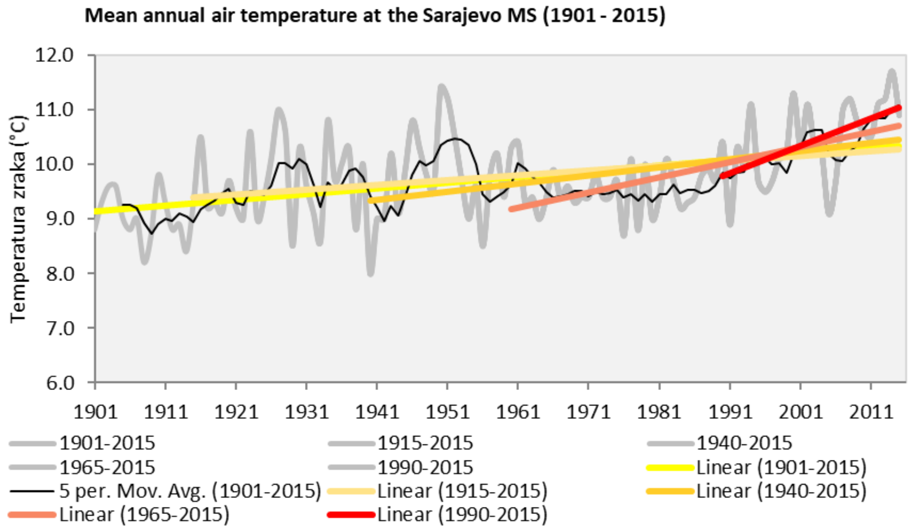


CHART 4. *Mean annual air temperature at the Sarajevo MS (1901 - 2015)*

There is a significant increase in the spring and summer air temperature values throughout Bosnia and Herzegovina. Trends in the summer season are the largest and range from 0.4 to 0.5°C/10 years and are a major contributor to the annual trends. Trends in the spring season are positive and range from 0.2°C/10 yrs. to 0.3°C/10 yrs.; winter season trends range between 0.3°C/10 yrs. and 0.4°C/10 yrs. The smallest trends are in the autumn amounting to approximately 0.2°C/10 yrs., and are negligible. Trends during the growing season within the observed period are significant and amount to 0.4°C/10 yrs.

Analysis of temperature extremes, i.e. the number of days with air temperature exceeding certain thresholds, e.g. the number of cold days (Tmin <0.0°C) or the number of warm days (Tmax ≥25.0°C), shows that the biggest changes were recorded in the number of cold days and the number of warm days. The following was observed: positive and increasing trends in the number of warm days and warm nights, and negative and increasingly pronounced trends in the number of cold days and cold nights.

At the meteorological stations in Sanski Most and Tuzla, the number of cold days has a negative trend and is reduced by 3 days per 10 years. The number of warm nights (Tn 90%) and warm days (Tn 90%) have a statistically positive trend and an increase of 3 to 5 days per 10 years. A negative trend was observed in the number of cold nights (Tn10%) and cold days (Tx10), and it decreases by 1 to 2 days per 10 years.

When it comes to precipitation in the same observed period, we can conclude that the average amount of precipitation did not sustain any significant change compared to the reference timescale 1961 - 1990. There was a slight increase in annual precipitation amount in the period 1991 - 2017, but there were certain changes in their distribution within the year.

According to data on the average water balance, Bosnia and Herzegovina is rich in water, but the intra-annual distribution of precipitation is not favorable as there is a pronounced spatial and temporal imbalance in the distribution, especially in the south of the country during the summer dry periods, when requirements for water are biggest.

Changes are more pronounced by seasons than on an annual basis and are reflected in the deficit of precipitation during the summer months (up to -20%) and a significant increase in precipitation during the autumn, especially in the north-eastern and central parts of the country, while spring and winter precipitation show no significant deviations (within 10%). Although no significant changes were recorded in precipitation levels, the pluviometric regime or annual distribution was largely disrupted.

Due to increased precipitation, flood risk is increased, especially in the northeastern part of Bosnia and Herzegovina, where catastrophic floods occurred in May 2014.

Between 2010 and 2017, we witnessed extreme precipitation with rainfall and floods of high intensity (2010, 2014), as well as intense processes of water erosion and landslides as a result of various anthropogenic impacts accompanied by fires and similar extreme occurrences. The results of the precipitation analysis indicate:

a) The stagnation of the trend of total precipitation, but also the unfavorable intra-annual distribution;

b) A further increase in air temperature and evapotranspiration whose expected increase conditions the decrease in surface runoff and infiltration of effective rainfall, and thus the provision of required water reserves for the plant;

c) An increase in variability within annual changes with the occurrence of prolonged dry periods,

d) The occurrence of fleeting heavy rainfall, the increase of which allows for the possibility of intensification of the occurrence of high water levels and associated floods.

In addition to drought, being a long-lasting phenomenon and occurrence, agricultural crops sustain severe damage from extremely high air temperatures. Absolute maximum air temperatures above 35°C have been recorded in almost all areas in Bosnia and Herzegovina, except the mountain range. Heat stress has a negative impact on the development of agricultural crops and is increasingly common. It mostly affects Herzegovina, but according to data for the 1961 – 1990 timescale, it became increasingly frequent in the northern, northeastern and continental parts of the country, which are very important for agriculture. In addition to the increase in air temperature, there was an increase in maximum topsoil temperature, which accelerates the loss of soil moisture and the mineralization of organic matter.

Although there are significant regional differences in expected climatic conditions, the predicted impact in Bosnia and Herzegovina in the 21st century will be reflected in an increase in air temperature, droughts during the summer months, as well as the occurrence of extreme events in terms of quantity, distribution, and intensity of the precipitation.

According to the projections of the future climate, agriculture in Bosnia and Herzegovina will be characterized by the struggle for water and the struggle with water, i.e. the lack of water and the longer drought periods on the one hand, and the floods on the other.

Shallow soils with low humus levels and low water retention capacity will be subject to increasingly frequent droughts and loss of yield. Compact soils with the poor water-air regime and low level of humus will be susceptible to flooding due to the inability to absorb water, i.e. runoff and waterlogging.

What awaits us in the future?

The development of appropriate strategies aimed at adaptation to climate change requires a perception of the future climate. According to various scenarios of the future climate that are being developed by the IPCC, it is evident that climate change in Europe has already occurred and that it will have far-reaching effects on both human well-being and nature.

Available results of regionalization and three climate scenarios for Bosnia and Herzegovina that were prepared for the purpose of the Third National Communication on Greenhouse Gas Emissions of Bosnia and Herzegovina show that climate change will be more substantially manifested in the next period across the country.

By the end of the 21st century, all three scenarios show a continuous rise in temperature. According to scenario RCP8.5[11], the temperature rise in the first three decades ranges between +1.6 and +2°C, but for the timescale 2071 - 2100 this range is +5.4 to +5.8°C. The temperature rise is slightly smaller according to scenarios A2 and A1B.

According to scenario RCP8.5, the changes of mean temperature for the DJF (December – January - February) and SON (September – October - November) seasons are higher (2.2°C) for the first thirty-year period 2011 - 2040 compared to the changes for the MAM (March - April - May) and JJA seasons (June - July - August) (1.2 to 1.6°C). For the remaining two periods, 2041 - 2070 and 2071 - 2100, the difference between the temperature changes in DJF, SON, and JJA seasons is smaller, so for the period 2071 – 2100 they range from 5.2 to 6°C. The change for the MAM season for the period 2071 – 2100 is smaller compared to other seasons and ranges from 4.6 to 5°C.

The increase in maximum temperatures is given through the number of summer days (days with a maximum temperature above 25°C). The number of summer days is projected to increase. At the annual level for the period 2011 – 2040, the index change ranges from five days in higher altitude areas to ten days in the northern parts, and to more than fifteen days in the south of the country.

For the summer season (JJA), these changes range from three to twelve days. For the second period, from 2041 to 2070, changes in the number of summer days range between 15 to 40 days, with about 30 days in the north and over 40 days in the south of the country. The JJA season has changes ranging from 10 to 30 days.

When it comes to the last period, 2071 - 2100, changes are within the range of 40 to 90 days at the annual level, and in this period the difference between the northern and southern parts is less pronounced.

[11] A Representative Concentration Pathway (RCP)

The expected increase in the number of days with higher temperature during the summer months will lead to critical consequences for the living world. The occurrence of extremes in short periods of time will lead to damage to crops (e.g. negative effects of extremely high temperatures that will reduce the amount of water in the fruits, cause burns on the plants, etc.). Their effects – drought and reduced water resources, combined with increased evaporation will endanger the ecosystem as a whole.

Future change in total precipitation by 2040 has a positive sign, with an anomaly of up to +5%. For the remaining two periods, the anomaly is negative and ranges from -10% to -20%. The spring MAM and summer JJA seasons will be marked by a decrease in precipitation for further time horizons, which is particularly pronounced for the summer JJA season, where the southern parts of the country will have a negative anomaly of -40% in the period 2071 - 2100. Changes in total precipitation are more pronounced by seasons than on a yearly basis. Changes in the seasonal distribution of precipitation within one year relative to the „baseline“ period are reflected in the deficit of precipitation during the summer months, and the increase in the amount during the autumn, while spring and winter precipitation show no significant deviations -5/+5%. A very small decrease in the mean annual precipitation (up to 10%) is projected at the annual level by 2040, which will have no significant impact on the total annual amount.

The projected changes in the total precipitation by seasons in the period 2011 – 2040, are of different nature. In winter, it is expected that the total precipitation will decrease by up to 5%. Total precipitation is expected to decrease by 40% in summer. A 5% increase in total precipitation is projected in the spring and fall.

A reduction in mean annual precipitation (up to 20%) is projected by 2070 at the annual level. In the period 2041 – 2070, precipitation is expected to decrease in all seasons. The biggest decrease in precipitation (by up to 40%) will occur in summer and (by 20%) in winter. Unlike the RCP8.5 scenario for the period 2071 - 2100, all seasons in almost the entire territory have a negative precipitation anomaly relative to the reference period.

After having looked at possible climate change scenarios, it becomes apparent that the expected climate change will gradually lead to significant changes in different sectors, notably agriculture. Therefore, decision-makers responsible for the agricultural, energy, tourist, and water management sectors should consider the further impacts of climate change when developing strategic plans for the coming years and decades.

Table 5. shows the importance of climate as a driver of any threats to land, combined with human activities.

TABLE 5[12]. *Importance of climate as a driver for each soil threat as identified in the different chapters. High importance, low importance, or a combination of climate and human drivers.*

Threat	Climate high importance	Combination of climate and human activity	Climate low importance
Water erosion			
Wind erosion			
Decline in SOM - peatsoil			
Decline in SOM mineral soil	(long term)	(short term) Management most important	
Compaction			
Sealing			
Contamination		Main driver human activity	
Salinization			
Desertification			
Flood and landslides			
Biodiversity	When climate affect ecosystem	At ecosystem level- combination of climate and human activities	

[12] Jannes Stolte, Mehreteab Tesfai, Lillian Øygarden, Sigrun Kværnø, Jacob Keizer, Frank Verheijen, Panos Panagos, Cristiano Ballabio, Rudi Hessel; Soil threats in Europe; EUR 27607 EN; doi:10.2788/488054 (print); doi:10.2788/828742 (online)

ADAPTATION AND SUPPORT IN IDENTIFICATION AND APPLICATION OF THE BEST PRACTICES OF SUSTAINABLE LAND MANAGEMENT

3

3.1. LAND DEGRADATION NEUTRALITY

Land degradation neutrality or LDN is a new initiative aimed at halting the ongoing loss of healthy and quality land through its degradation. The UNCCD defines land degradation neutrality as „a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems". The goal is to balance the losses over time in order to achieve a state with no net losses of healthy and quality land. The land/soil function in the LDN concept is aimed at:

- Maintaining and improving ecosystem services;
- Maintaining or improving soil productivity to ensure food security;
- Increasing the resilience of the land and populations dependent on the land;
- Seeking synergies with other environment protection goals;
- Reinforcing a responsible land management and land use.

The LDN sets the task of managing land degradation by promoting a two-way approach to measures to avoid or reduce land degradation, coupled with efforts to reverse past degradation (Figure 7.). LDN looks at all forms of land degradation, whether caused by human or natural impacts (Cowie *et al.*, 2017) and ensures numerous benefits, whether environmental or social, or those relating to mitigation and adaptation to climate change. It is essential to include SLM measures in the process that will help prevent or reduce land degradation.

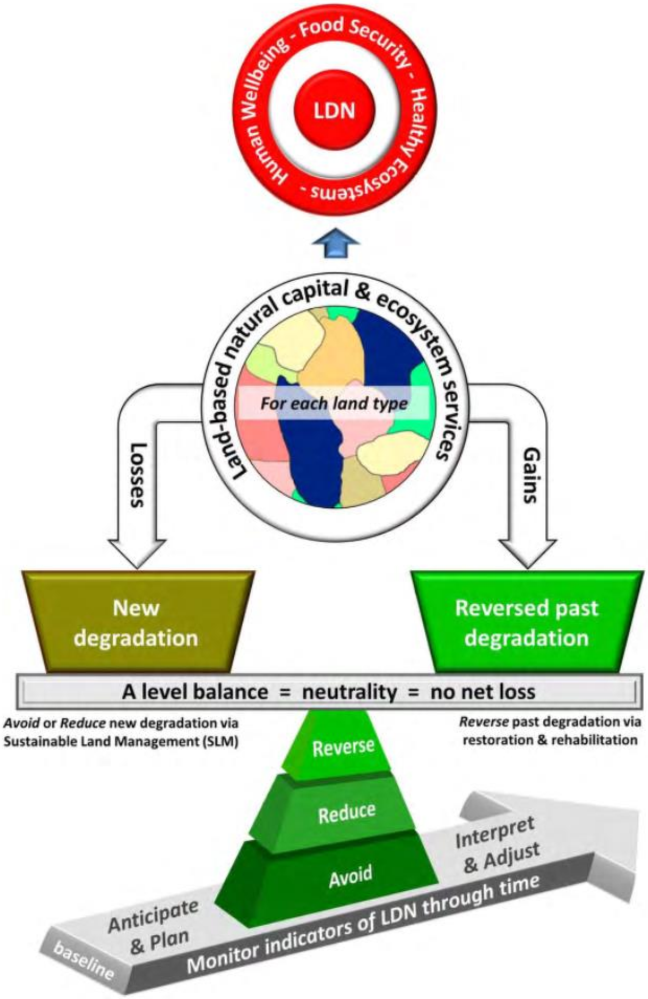


FIGURE 7[13]. *Key elements of the scientific conceptual framework for achieving LDN and their mutual relations*

The LDN concept has been incorporated in sustainable development goals (SDG), especially in its part pertaining to poverty, food security, environmental protection, and sustainable use of natural resources (UNCCD, 2016).

[13] Orr, B.J., A.L. Cowie, V.M. Castillo Sanchez, P. Chasek, N.D. Crossman, A. Erlewein, G. Louwagie, M. Maron, G.I. Metternicht, S. Minelli, A.E. Tengberg, S. Walter, and S. Welton. 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science - Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

A key SDG for the land is SDG 15., which encourages countries to protect, rehabilitate and promote the sustainable use of terrestrial ecosystems; manage forests in a sustainable manner; combat land desertification and degradation, and; halt and reverse land degradation toward its recovery thus stopping the processes of biodiversity loss. The SDG 15.3 target reads that it is necessary „by 2030, to combat desertification, restore degraded land and soil, including land affected by desertification, drought, and floods, and strive to achieve a land degradation neutral world“. A global indicator that identifies the status of change is defined in clause 15.3.1., and shows the „proportion of degraded land over the total land area“ (UNCCD, 2017).

By the end of 2020, it is planned to promote sustainable forest management, halt deforestation, restore destroyed forests, and significantly increase afforestation globally. Desertification should be combated, degraded land rehabilitated, and land degradation neutralized. Likewise, the conservation, rehabilitation, and sustainable use of terrestrial freshwater ecosystems and their environment should be ensured by the end of 2020, in accordance with obligations under international agreements. It is important to integrate ecosystem and biodiversity values into national and local planning, development processes and strategies to reduce poverty by the end of 2020. In order to achieve this goal, it is necessary to mobilize and significantly increase funding from all sources.

However, before we are able even to speak about the implementation and achievement of LDN goals, we need to define goals and ways to achieve them, as well as indicators that will help us assess the status and success in achieving the LDN goals. In this regard, the *LDN Target Setting Programme* was launched in 2014, which aimed to help participating countries to define the so-called „baseline“ for monitoring the LDN progress (three indicators: land cover change, land productivity, soil organic carbon content (carbon stocks)), LDN goals, and measures and projects to achieve and link to SDG targets, etc., on a voluntary basis by participating countries. The program provided each country participating in this process with technical support, access to a global database for all three indicators, as well as financial assistance for the development of an LDN baseline. So far, 122 countries, including Bosnia and Herzegovina, have joined the *LDN Target Setting Programme*, and according to the UNCCD, significant progress has been made since 2015 when the 2030 Sustainable Development Agenda was adopted.

There are three potential success scenarios for achieving LDN: 1) LDN exceeded, 2) LDN achieved, 3) LDN not achieved (Figure 8.).

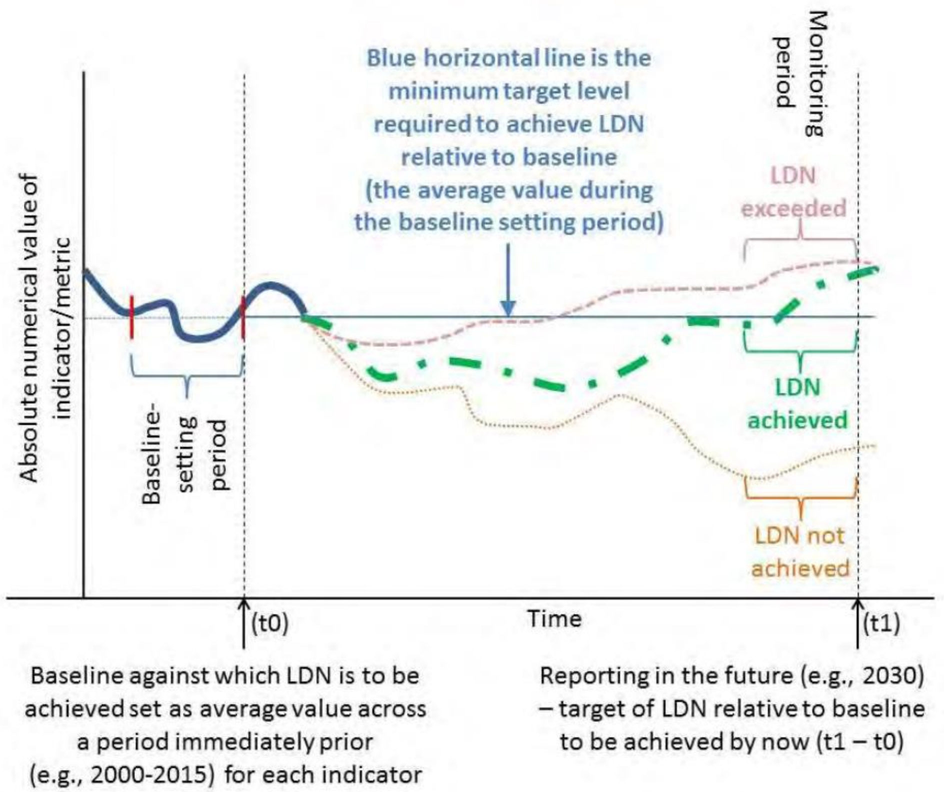


FIGURE 8[14]. *In LDN, the minimum target equals the baseline, because the LDN goal is no net loss. The diagram illustrates alternative trajectories for a hypothetical indicator/metric for the scenarios in which the LDN is achieved, exceeded, or not achieved.*

LDN is not an independent process, but a process that should be incorporated in the main national political development process of any country. Achieving LDN goals, contributing to land degradation neutrality by 2030, as well as achieving sustainable development goals - SDG, requires active involvement and strong support from the government, and from all stakeholders, groups and sectors influencing land resources.

[14] Orr, B.J., A.L. Cowie, V.M. Castillo Sanchez, P. Chasek, N.D. Crossman, A. Erlewein, G. Louwagie, M. Maron, G.I. Metternicht, S. Minelli, A.E. Tengberg, S. Walter, and S. Welton. 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science - Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Main LDN targets and sub-targets – achieving LDN by 2030 In the Federation of Bosnia and Herzegovina
1. Improve land quality and its protection, restore degraded soil functions in specific ecosystems, or minimize negative environmental impacts; 1.1. Land management in the function of environmental protection and spatial planning system; 1.2. Create a basis for harmonious and spatially balanced socio-economic development, with a focus on marginalized and degraded areas.

Experience of the Federation of Bosnia and Herzegovina in the implementation of LDN shows that the achievement of the set LDN goals and measures, in addition to political will, requires legislation, funding sources, social awareness and education about land and its functions in the ecosystem in general; the process also shows a great need for the development of indicators (Čustović and Ljuša, 2018). Experience has also shown a strong link between SLM and LDN, especially at the local level where land degradation is most visible and where SLM measures, even small-scale ones, can make major positive changes and contribute to achieving bigger goals, first national and then global.

3.2. Mainstreaming And Scaling Up Good Practices - *Mainstreaming Strategy*[15]

The DS-SLM[16] Mainstreaming Strategy is an integral part and key component of the DS-SLM Support Framework of the DS-SLM project *(Module 1: Operational Strategy and Action Plan for mainstreaming and scaling out SLM).*

In general terms, the objective of DS-SLM mainstreaming strategies is to strengthen the contributions of DLDD and SLM methodological assessments, tools and project findings to key decision-making processes for the uptake of SLM practices.

[15] See: Bastidas Fegan, S. 2019. The DS-SLM Sustainable Land Management Mainstreaming Tool - Decision Support for Mainstreaming and Scaling up Sustainable Land Management. Rome. FAO. 44 pp. Licence: CC BY-NC-SA 3.0 IGO.
[16] DS-SLM - Decision Support for Mainstreaming and Scaling up of Sustainable Land Management

Thus, DS-SLM mainstreaming strategies should:

- Establish a pathway for integrating SLM into national and decentralized policy, planning and finance related decision-making processes that can facilitate SLM implementation and scaling out.
- Establish activities for mainstreaming SLM in coordination with key institutions and stakeholders.
- Provide long-term support for the implementation of SLM.
- There are differences between the concepts of mainstreaming and scaling up (Diagram 1.). In the DS-SLM project, however, they are generally considered together under the term mainstreaming, with a view to better contextualizing and separating the mainstreaming/scaling-up process from the idea of implementing and replicating („scaling out") SLM technologies.

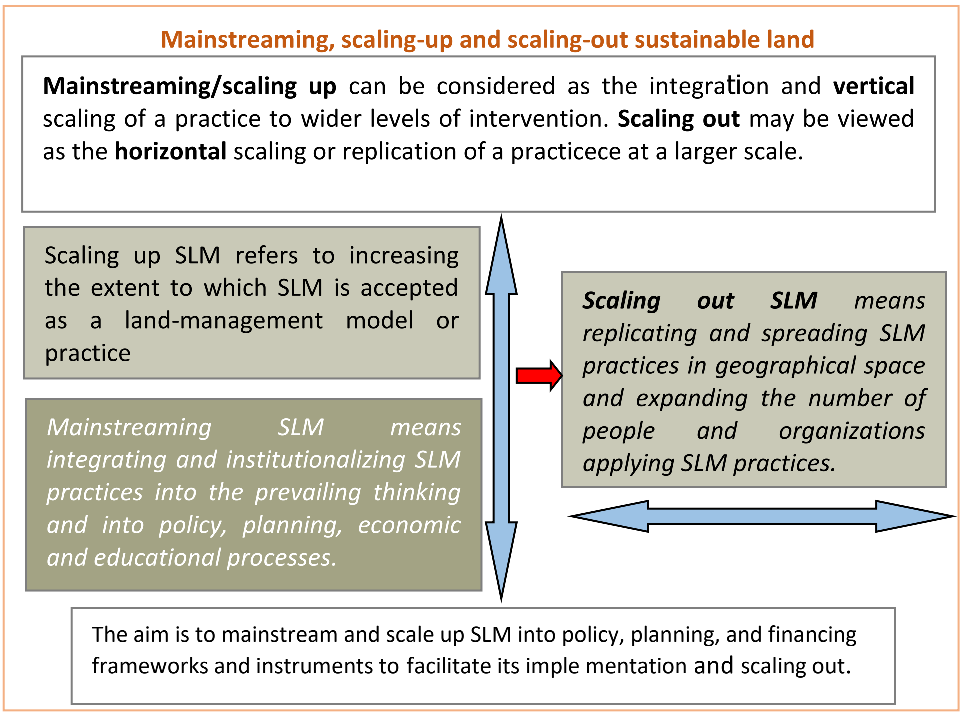


DIAGRAM 1. *Mainstreaming, scaling-up and scaling-out sustainable land management (Bastidas Fegan, S. 2019)*

Key elements of DS-SLM Mainstreaming strategies:

- In formulating DS-SLM mainstreaming strategies, the idea is to go beyond the traditional approach of mainstreaming the results of pilot projects through the production of policy briefs or by inviting relevant institutions to share project findings at events.
- A DS-SLM mainstreaming strategy should be a simple, proactive, and strategic process in which activities for mainstreaming SLM are planned, developed and monitored.
- DS-SLM mainstreaming strategies should focus on a few viable mainstreaming strategic objectives and activities that the DS-SLM project team and its partners can undertake during project implementation that can integrate SLM or at least trigger a process for doing so that will have longer-term impacts – beyond the end of the project (e.g. integrating SLM into an existing incentives mechanism or integrating project findings into an existing land-use planning process).
- The point of departure for a mainstreaming strategy should be to overcome barriers to the implementation of SLM (such as a lack of incentives) by integrating SLM into key decision-making processes.
- DS-SLM mainstreaming strategies should focus on knowledge management, capacity building and partnership building.
- Assessments of DLDD and SLM best practices, together with other existing and related information, can serve as inputs for deciding why, where and for what kind of practices incentives should be oriented. Partnerships can be built with key institutions to develop the multi-institutional assessments required to integrate SLM into existing incentive mechanisms or to create new incentives mechanisms that will enable farmers to implement and scale-out SLM practices.
- Existing decision-making processes at the national and subnational levels may hinder or facilitate the implementation of SLM. DS-SLM mainstreaming strategies should identify key decision-making processes that represent opportunities for promoting SLM.
- DS-SLM mainstreaming strategies can be developed at the national, subnational and local levels.

3.3. Participatory Land Use Development (PLUD[17]) and Implementation of SLM Measures

More than 6,000 years ago, agriculture spread to almost every continent. The natural flora and fauna have been replaced by advanced technologies for the establishment of invasive plant and animal populations. Since 1750, a land transformation has started to accelerate and so has the land use change. People chose areas that were most suitable for agricultural production, the emergence and expansion of human settlements, the development of infrastructure, and the living conditions in general. All interventions were based on meeting human needs (food, clothing, profit) without taking account of whether and to what extent the environment, biodiversity, aesthetics, basic principles of sustainable development, and the like are endangered (Čustović *et al.*, 2013).

People's requirements and demands change and this often entails more intensive use of land and all other resources. It is necessary to make a plan as to how to optimally use the land, because once the land is wasted it is lost forever. Land use development planning should contribute to sustainable development and management of land and other natural resources, sustainable development and economic strengthening of the local community, protection of people and resources from natural disasters, reduction of conflicts in land use, identification and implementation of SLM measures, and any other activities that directly or indirectly contribute to the sustainable development of an area. The process itself is an opportunity to identify the needs of different land users, and to prevent or resolve specific conflicts through negotiations.

The FAO land use development (planning) model is a function of four interdependent factors: legislation, social norms, land, and markets. The model shows that each of these factors influences one another by creating changes in land use, which should not be regarded as directly made, but as changes resulting from the manipulation of one or more factors acting together and forming a land use (FAO, 2007).

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[17] The PLUD methodology was developed within the project „Inventory of land resources in Bosnia and Herzegovina in the post-war period“ (GCP/BIH/002/ITA). A detailed description of PLUD can be found in the handbook „Participatory Land Use Development in the municipalities of Bosnia and Herzegovina”, revised edition, 2007.

At the very center of the process are stakeholders, primarily local actors who have the most interest in developing the land they live on and whose opinions and ideas can affect the ultimate outcome of the process. The interested party or stakeholders can be anyone (an individual, group, or institution), i.e. all those having desire and motive as well as the interest to participate in the land use development process.

Current practice in Bosnia and Herzegovina has shown that the most important stakeholder is the municipal administration which is in charge of and responsible for the development of the municipality, and therefore for the sustainable use and development of resources. Stakeholder analysis (their interest, influence, control over resources, knowledge and information, motivation to participate, ownership of land and resources, etc.) is crucial to the process, as it can help to better understand the stakeholders, their interests, influences and motives, which can certainly contribute to the success of the process itself. PLUD and the implementation of SLM measures entail several basic implementation phases that are outlined and described below.

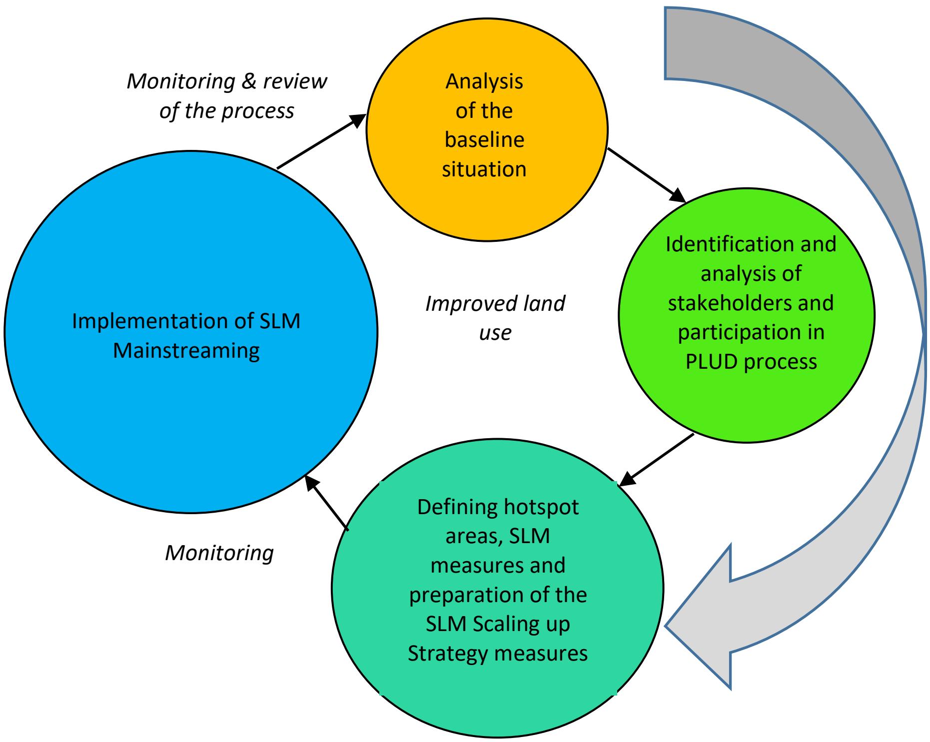


DIAGRAM 2. *Key phases of PLUD/SLM process at the local level*

Analysis of the initial (baseline) state

At this stage, an inventory of the existing state of land resources is conducted as well as an analysis of key pressures on land and land management issues. Practice has shown that the Land Use Value Map is the most effective tool for inventorying conditions and problems, which creates the basis for all future activities and projects related to the development, protection and sustainable management of land and space in general.

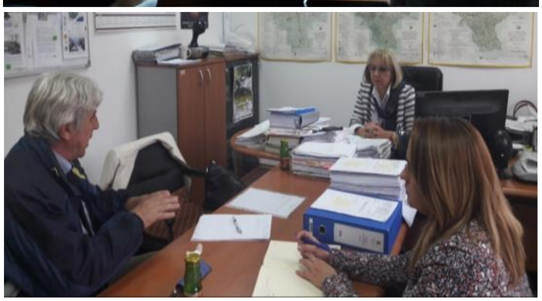
Identification and analysis of stakeholders and participation in PLUD process

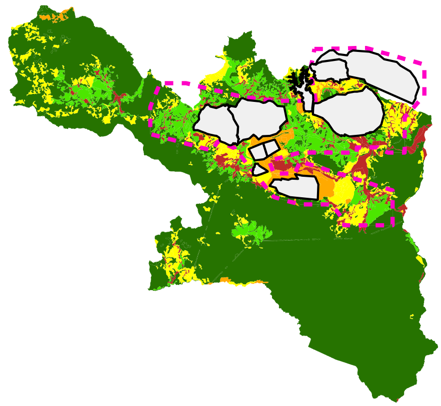
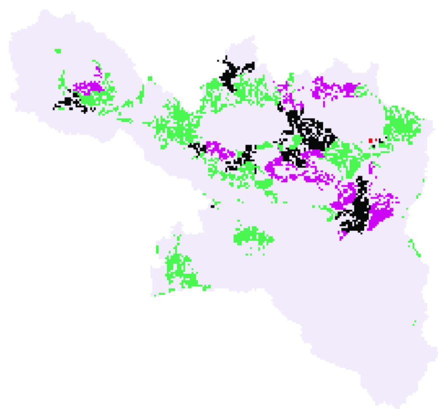
This analysis involves the identification and analysis of stakeholders who can contribute to the development of land use and the implementation of SLM. Depending on the set goals and processes, stakeholders may be different. In the case of the PLUD/SLM approach, cantons, regions, municipalities, and local farmers and farmers' associations were identified as key stakeholders.

Defining hotspots, SLM measures and preparing the Sustainable Land Management Mainstreaming Strategy measures

Initial Workshop and PLUD meetings

This phase begins with an initial workshop intended to present the goals and define further steps of the process. After the initial workshop, numerous regular consultation and coordination meetings with stakeholders are conducted in order to define hotspots, priority projects, SLM measures, ways of integrating SLM practices, etc. Round tables and thematic



<table>
<tr><td>conferences proved to be a very important segment of the PLUD process.</td><td></td></tr>
<tr><td>Ecological-economic and agro-ecological zoning and defining of hotspot areas are among the initial tasks.
Ecological-economic zoning involves the division of some space into specific zones (for example agricultural, forestry, exploitation, etc.).
Agro – ecological zoning, on the other hand, deals with determining the suitability for the cultivation of individual crops within agricultural zones and is an integral part of the map of land use value.
This division makes it easier to recognize the condition, potential, and opportunities of a land area, to identify hotspots, and then prioritize areas in view of identifying, directing and implementing SLM measures to reduce, rehabilitate and prevent land degradation.</td><td>
</td></tr>
<tr><td colspan="2">Identification of SLM technologies
This phase involves the identification of SLM technologies implemented in the country, as well as those from the WOCAT database, which could be successfully implemented at the studied site.</td></tr>
<tr><td colspan="2">Preparation of the Strategy for Mainstreaming SLM Technologies
The key document for the sustainable implementation of SLM technologies is the so-called Mainstreaming Strategy that describes problems, priorities, policies, SLM technologies to be implemented, financing methods, etc. This is a key document that should enable the continuity and sustainability of a specific</td></tr>
</table>

SLM technology.

Capacity building of the parties involved

Depending on the chosen SLM technologies, it is advisable to educate stakeholders who could participate in mainstreaming and upscaling SLM technologies (e.g. training in contour farming in Srebrenik). One of the lessons learned shows that it is also necessary to establish educational experiments (e.g. Growing blueberries in containers on degraded land in Živinice), especially if these are new measures farmers are not familiar with. Promoting and scaling up SLM requires a continuous capacity building of decision-makers (e.g. work with the municipal administration and in the field where land consolidation is performed) and dissemination of information through the media.

Growing blueberries in containers at a tailing disposal site Višća – Živinice (left)
Growing blueberries in containers on heavy hydromorphic soils in Živinice (right)

Training of farmers in contour tillage in Srebrenik

Process monitoring and sustainability

Monitoring of the implemented activities planned by the SLM Mainstreaming Strategy measures should demonstrate the success in implementing the scaling up of good practices, new opportunities and requirements that will enable continuity and sustainability of the process of mainstreaming a particular technology. Monitoring, as a regular process, brings us back to the initial state (baseline) which gives us a clear picture of the success of the overall process and the basis for further planning and revision of the planned activities. One of the important segments of analysis and monitoring of new technologies, in addition to the technical and technological aspects, is the analysis of socio-economicic indicators (including gender) of the success of the implemented technologies.

The participation of different stakeholders in the land use development process significantly contributes to the identification and implementation of SLM in practice, since without local actors there is neither mainstreaming nor scaling up of SLM measures. To facilitate spatial interventions, actors also need the support of the academic community, technical institutions, governments, and others who can in any way support sustainable resource management, especially when it comes to the preparation of the Map of land use value and the Strategy for mainstreaming sustainable land management. Financial support to farmers is crucial, and in this concept, through incentives and rural development measures, support should be provided to those farmers working on the adoption and implementation of protection and sustainable land management, which should definitely be defined by the Strategy for scaling up SLM measures, as well as other strategic documents at the local level.

The participation process is also crucial from the standpoint of the implementation of the „2030 Agenda for Sustainable Development”. The sustainable development goals deal with the global challenges we face, among which environmental degradation plays a significant role. SDG 16.7 encourages countries to ensure responsible, inclusive, participatory and representative decision-making at all levels, which speaks volumes about the importance of the participation of different stakeholders (NGOs, local communities, etc.) in the planning and decision-making process at all administrative levels.

3.4. Knowledge Sharing, Creation Of Database And Selection Of Best Practices For Implementation (WOCAT)

WOCAT – World Overview of Conservation Approaches and Technologies

www.wocat.net

There are numerous platforms in the world with advanced technologies that support environmental protection and sustainable resource management. Some platforms have very rich and developed databases and others do not, depending on resources, experience, and the level at which they address these issues, be it global, regional, or national. One of the most relevant platforms with a highly developed database and considerable experience at the global level when it comes to the SLM approach is WOCAT – The World Overview of Conservation Approaches and Technologies.

WOCAT is a global network established in 1992 t o compile the most important documents on SLM practices, evaluating them, and sharing knowledge on the implementation of sustainable land management practices and knowledge. Being one of the first to recognize the vital importance of SLM and pressures exerted by the lack of knowledge on land management, the UNCCD has formally recommended WOCAT as a core global database on best SLM practices since 2014.

The global WOCAT network brings together a consortium of partner institutions, formally defined as WOCAT International. Members of the WOCAT consortium are FAO, GIZ (Germ. *Deutsche Gesellschaft für Internationale Zusammenarbeit*), ICARDA (*International Center for Agricultural Research in the Dry Areas*), ICIMOD (*International Centre for Integrated Mountain Development*), CIAT (*International Centre for Tropical Agriculture*), ISRIC (*World Soil Information*), SDC (*Swiss Agency for Development and Cooperation*) and CDE (*Centre for Development and Environment*) of the Bern University.

An integral part of the WOCAT network are the institutions that have signed the Memorandum of Understanding thus joining the network on the principles of self-organization, autonomy, decentralization, and self-funding. In accordance with these principles, in early October 2018, a total of 1,226 institutions from all over the world were in the WOCAT network. WOCAT network can also be joined by regional or national initiatives established and active in the areas of interest to the WOCAT network.

WOCAT international

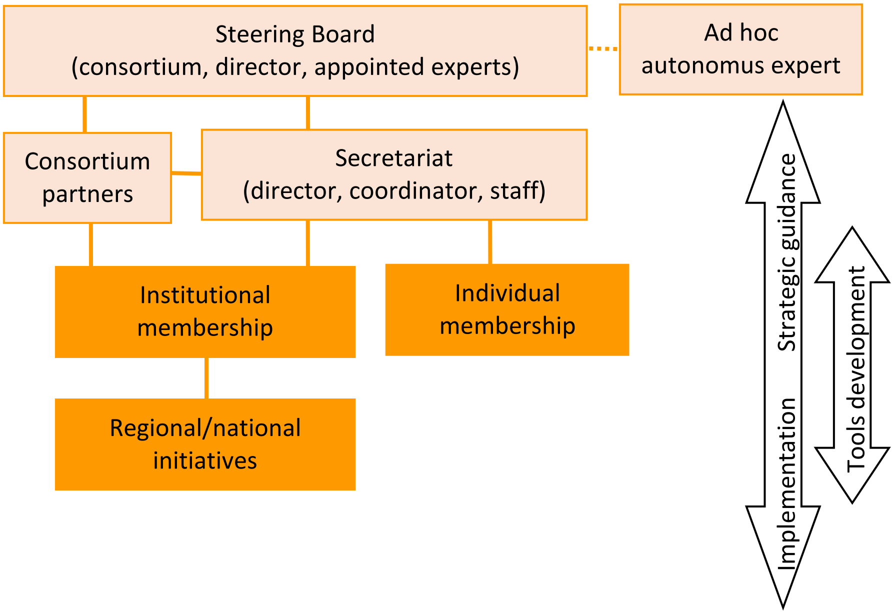


DIAGRAM 3. *WOCAT Organizational Structure*

The main reasons for setting up, maintaining and developing the WOCAT network commonly include poor operational and lack of adequate institutional governance and regulatory frameworks for addressing the increasing pressures on limited resources, which results in degradation of land that many rural communities, as well as the society as a whole, depend on. Today it is certain that, without appropriate public pressure, political will and knowledge-based decision-making tools, the management of land resources will remain ineffective. This also means that valuable knowledge and practices that have been implemented in certain areas for years, will only be applied selectively.

The official vision of the WOCAT network is to observe land degradation through the implementation of SLM practices in order to improve the quality of land resources, and thus strengthen the functions of other ecosystems, i.e. the quality of life of humans, through the dissemination, enhancement and use of knowledge about sustainable land management.

The mission of the WOCAT approach is to support adaptation, innovation and decision-making regarding sustainable land management through technologies that increase land productivity and water efficiency and improve ecosystem services delivery.

All the above is complemented by the knowledge of the importance of sustainable use and management of biodiversity being in the function of the most important goals for man and animals, and that is to contribute to the provision of sufficient amounts of food and to adapt to climate change, as well as to reduce the risk of natural disasters.

In a nutshell, the vision and mission of the WOCAT platform can be achieved through the following important tasks:

- Developing and maintaining an effective global network of SLM experts for sustainable land development (roster – list of names), developing partnerships and promoting synergy;
- Developing standardized tools and methods for managing knowledge and supporting decision-making at local, national and global levels;
- Building and maintaining a global knowledge base on sustainable land management;
- Improving the capacities and knowledge base of different stakeholders through the development and distribution of educational materials for training courses and various publications.

Based on the vision, mission and tasks of the WOCAT network, it could be concluded that WOCAT seeks to promote globally the successful practices of sustainable land management that are implemented locally, i.e. practices that prevent or mitigate the effects of land degradation.

WOCAT tools and methods

Originally established as an informal global network of experts in soil and water protection and conservation techniques, WOCAT has expanded its courses of action over time. The beginnings were related to the implementation of simple standardized tools for documenting, supervising and evaluating the effects of sustainable land management measures, to create a knowledge base by developing flexible modular methodologies for evaluating sustainable land management practices. Recently, WOCAT has been promoting the development of methodologies for using the knowledge base to make informed and comprehensive decisions concerning sustainable land management. This is possible because of the effort that has been made over a number of years in the area of promoting and documenting the so-called technologies and approaches to sustainable land management.

Sustainable land management technology is defined as a „physical practice consisting of one or more measures to control land degradation and/or increase its productivity“.

An approach to sustainable land management involves a description of the technological process and method for implementing one or more SLM technologies, including technical and financial support, stakeholders' engagement, etc.

In order to document and present approaches and technologies of sustainable land management, specific questionnaires were designed for this purpose and refined over time. The purpose of the questionnaire is to provide a comprehensive outline of the approaches or technologies, including their effects, as well as the cost of introducing and maintaining certain technology. The completed Questionnaire Approach (QA) (https://www.wocat.net/library/media/16/), or Questionnaire Technology (QT) (https://www.wocat.net/library/media/15/), after being reviewed by the WOCAT Secretariat, may be included in the WOCAT database on sustainable land management approaches and technologies. The objective of documenting and evaluating land management practices is to disseminate and share knowledge about land management, support decision-making based on documented facts, and promote proven good practices. Practice documentation can only be made with the analysis of field experience and with a full understanding of the reasons underpinning the implementation of successful practice in sustainable land management.

When it comes to preventing or reducing land degradation, or to restoring degraded land by improving land management technologies and approaches enabling their implementation, all practices can be considered, including the possibility of their upgrading and adjustment to local needs, regardless of the technology involved, whether traditional and related to a narrow area or new one promoted through programs, projects or initiatives at regional and global levels. Important answers in the questionnaire should help identify the specificity of the studied technology, scope of inputs and cost of its establishment and maintenance, the state of the social and natural environment in which it is implemented, and its potential effects and impact on human well-being and the ecosystem.

The answer should also consider information on the implementation of practices, including capacity building, decision-making methods, the technical and financial support provided, a requirement for changing regulations and policies that should enable the implementation of SLM practices.

WOCAT recommends that the questionnaires be completed by teams of experts in sustainable land management, with different profiles and experiences, who are familiar with the details of SLM technology (technical issues, financial, socio-economicic environment, etc.). The participation of land users, or anyone introducing or already implementing technology or approach, is essential.

In addition to the basic questionnaire implemented by WOCAT and other partners (especially FAO) in previous projects, other approaches and assessments have been developed as well, particularly with regard to degraded land mapping and management (QM - *Questionnaire of mapping*), developed through the collaboration of the WOCAT network and LADA[18] and DESIRE[19] projects. Along the way, other approaches are being developed to assess the state of natural resources such as water management (QW - *Questionnaire of water management*) or climate change adaptation (QCCA - *Questionnaire of climate change adaptation*).

Overview of some of the approaches and technologies for sustainable land management from the WOCAT database

In early July 2019, the WOCAT database had about 1,075 sustainable land management technologies, 461 sustainable land management approaches, and 443 practices that the UNCCD recommends as PRAIS practices[20]. This number of developed approaches and practices relating to sustainable land management technologies is a result of answers provided in the questionnaires by 131 countries worldwide. Table 6. provides, based on the situation in early July 2019, an overview of the ten leading countries according to the number of sustainable land management technologies documented and integrated into the WOCAT database on sustainable land management technologies and approaches.

[18] Land Degradation Assessment in Drylands

[19] Desertification, Mitigation, and Remediation of Land

[20] UNCCD PRAIS practice is a recommended sustainable land management practice previously integrated into the UNCCD PRAIS system within the UNCCD reporting ptocess.

The table shows that all ten countries are from Africa and Asia. This indicates that land degradation problems are much more pronounced in (primarily) African and Asian countries, and these are mostly developing countries, with the exception of China. It is also possible that international organizations and programs dealing with the problems of land degradation and land protection paid more attention and allocated more resources to countries affected by this problem to a larger extent.

TABLE 6. *Overview of countries with the largest number of sustainable land management technologies and approaches to sustainable land management in the WOCAT database*

No.	Country	# technologies	No.	Country	# approaches
1	Tajikistan	112	1	Tajikistan	57
2	Kenya	59	2	Nepal	31
3	Ethiopia	58	3	Kenya	28
4	Uganda	51	4	Ethiopia	25
5	Nepal	48	5	South Africa	25
6	Cambodia	37	6	China	23
7	Philippines	36	7	Mali	20
8	Nigeria	32	8	Uganda	14
9	Senegal	32	9	Nigeria	13
10	Tanzania	32	10	Morocco	11

The relationship between the degree of poverty and the state of land degradation is shown in Chart 5., provided by Nachtergaele *et al.* (2009). Land degradation processes are most pronounced in countries with high levels of poverty, where 40% of total land areas of those countries are either highly degraded or under strong degradation processes. The share of such land in medium-poor countries is 30% and 20% in the countries with low poverty. Moderate degradation trends and moderately degraded land are more pronounced in countries with a low or medium level of poverty. Improved land or land whose properties have been improved are more represented in rich (30%), and medium-poor (20%) countries, whereas in the poorest countries it is 10%.

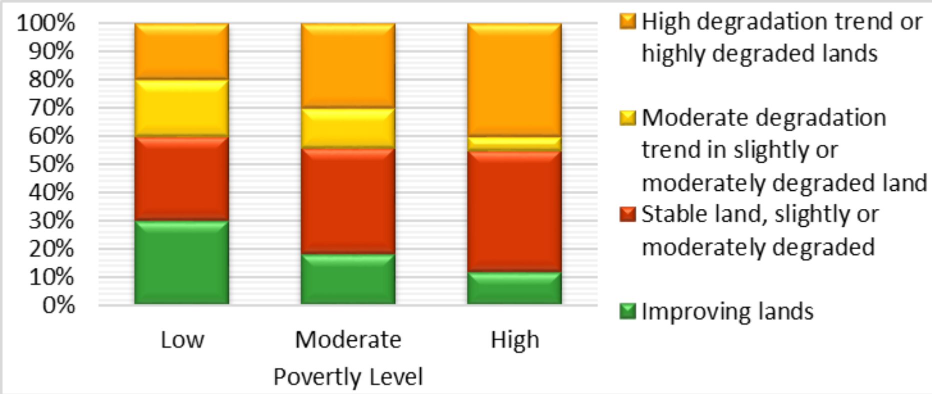


CHART 5. R*elationship between land degradation and the degree of poverty in a country (Nachtergaele et al., 2009)*

For our circumstances, it is very important to know how the problems of sustainable land management and the presentation of SLM technologies unfold in some European countries having problems and conditions similar to those in Bosnia and Hercegovina. Table 7. presents the number of SLM technologies and SLM approaches from European countries documented in the WOCAT database. It shows that, by the beginning of July 2019, twenty-five European countries had integrated their data into WOCAT: 168 SLM sustainable land management technologies and 50 approaches to sustainable land management.

TABLE 7. *Number of SLM technologies and SLM approaches documented in WOCAT database from European countries*

Country	# of technologies	# of approaches	Country	# of technologies	# of approaches
Spain	29	6	Romania	4	1
Italy	19	3	Slovenia	4	0
Switzerland	17	6	Cyprus	3	1
Greece	13	6	Bosnia and Herzegovina	3	0
Netherlands	9	1	Iceland	3	1
Germany	8	3	Estonia	3	0
Russian Federation	8	3	Slovakia	3	1
France	8	1	Belgium	2	1
Great Britain	7	6	Norway	2	1
Portugal	7	1	Sweden	1	1
Turkey	5	4	Serbia	1	0
Hungary	4	2	Ukraine	1	0
Poland	4	1	**Total**	**168**	**50**

Four countries: Spain, Italy, Switzerland and Greece recorded the largest number of SLM technologies. It should be noted that three SLM technologies from Bosnia and Herzegovina are also accepted in the WOCAT database. Of the countries in the neighborhood of Bosnia and Herzegovina, only Slovenia (4 technologies) and Serbia (1 technology) have documented sustainable land management practices in the WOCAT database.

It should also be noted that five countries (Serbia, Ukraine, Slovenia, Estonia and Bosnia and Herzegovina) have SLM technologies that are incorporated into the database, but no SLM approaches, although according to the WOCAT network's guidance, each SLM technology should in principle be coupled with SLM approach, leaving the possibility for a single SLM approach to be linked to multiple SLM technologies.

Annex 1. provides a brief overview of all 168 integrated SLM technologies, with their original names, a very brief description and a link to the WOCAT database, thus providing broader insight into SLM technologies in European countries.

Annex 2. gives a brief overview of 48 SLM approaches submitted by 20 European countries (excluding the two apparently the same approaches documented from Switzerland).

In Annex 2., we can see that SLM approaches also include those of relatively broad, general relevance (e.g. platform for open discussions on sustainable land management from Germany, or rural development regional program from Spain), or narrowly specific approaches (e.g. mobile gardens in local communities from Germany, or sustainable development of olive farming through the promotion of covering the land with plastic nets and its no-tillage maintenance from Greece). Some SLM approaches could be characterized as practices, which especially among agronomists, are regarded as common knowledge and are widely spread (e.g. production of fodder or minimum water consumption through the promotion of drip irrigation system from Turkey, and the like).

3.5. Economic Valorization Of The Implementation Of SLM Measures

The method for determining the economic valorization of the best practice implemented is a cost/benefit analysis, which establishes the relationship between the cost of its introduction and maintenance, and the benefits gained from it, in the short and long term. It is a highly complex analysis which entails knowledge not only of the method chosen but also of all local specificities since both the cost and expected benefits from a given practice often depend on the local social, economic and biological context. Therefore, the technologies chosen cannot be stated in advance to be economically viable, nor generally acceptable, but are analyzed on a case-by-case basis to determine their economic viability.

Nevertheless, there is no generally accepted method for the economic valorization of best practices of sustainable land management, nor is there a method that would allow its accurate and reliable calculation. In addition, for a number of good practice measures that are in use and are considered economically viable, both by landowners and the community, no cost/benefit analysis has ever been conducted, therefore the accurate cost and benefit related information cannot be obtained from either the user or the local experts.

WOCAT approach to the economic valorization of SLM measures

When it comes to impact analysis of implemented SLM technology, WOCAT analyzes three types of impact: socio-economic, ecological and impact on a wide area. Each type lists the types of impact that are specific to a given technology and rates the technology impact on a zero-to-seven scale, with zero causing an extremely negative impact[21], and seven representing the maximum positive impact[22].

Cost/benefit ratio analysis is based on the rating of benefits versus initial investment and benefits in relation to the cost of maintaining the technology used. Both ratios are analyzed in the short and long term, by rating both short-term and long-term impacts on a scale of zero to seven, with zero being very negative and seven being a very positive impact, i.e. economic/financial effect for landowners.

[21] reduction, deterioration, hindering, cost increase

[22] increase, improvement, facilitation, cost decrease

In this way, SLM practices can be grouped by scenarios according to which the dynamic of gaining benefits will take place. The WOCAT database does not provide a precise quantitative analysis of the cost/benefit ratio. All costs associated with the introduction of an SLM technology as well as the cost of its maintenance, are specified by categories, whereas the short-term and long-term benefits are estimated, not calculated.

Giger, M., Liniger, H, and Schwilch G.[23] Published research findings on a sample of a total of 363 case studies of good and promising SLM practices, collected, documented and evaluated by the WOCAT network over a fifteen-year period ending in 2012. The research aimed to determine not only the technologies' cost-benefit ratio but also the economic benefits to local stakeholders. Most of the sample technologies that were analyzed were from Africa (167) and Asia (149), and significantly fewer from Europe (27), South America (17) and Australia (3).

By dominant activity, all technologies and measures analyzed were classified into one of four large groups: agronomic, structural, vegetative, and governance, although they mostly belonged to more than one group. The results of this comprehensive analysis showed that the vast majority of SLM technologies analyzed are perceived as profitable.

73% of them were rated as practices with a positive or neutral cost-benefit ratio in the short-term, while in as many as 97% practices the perception was that the long-term cost-benefit ratio was positive or highly positive. The authors of the study also concluded that in addition to benefits for landowners and land users, SLM practices bring numerous benefits to other stakeholders.

Regarding landowners' motives for implementing SLM practices, the most represented ones among the respondents were: increase in production (24%), increase in profit (20%), improvement of living conditions (20%); while only a small percentage related to raising awareness of environmental protection (9%). It is obvious that most of the landowners are guided primarily by economic motives when it comes to the implementation of SLM.

[23] Economic Benefits and Costs of Technologies for Sustainable Land Management (SLM): A Preliminary Analysis of Global WOCAT Data (2013)

3.6. Spatial Planning In The Function Of Sustainable Land Management

All human activities take place in a particular space, and therefore space is the most significant development potential of any country. Protection, rational use, planning, and regulation of space is the most important strategic activity of both the Federation of Bosnia and Herzegovina and each canton individually, as well as municipalities as basic units of local self-government. The desire for faster development and higher quality of life, alongside the growing processes of industrialization and urbanization, requires better and more elaborate mechanisms of land use and regulation of space relations. Space is the most important but increasingly scarce resource for sustainable development. Sustainable development implies ensuring that space is used in the way, which, while preserving the environment, nature, and permanent use of natural resources, and protecting cultural and historical heritage, meets the needs of current generations, without compromising equal opportunities to meet the needs of future generations. Therefore, sustainable development is a long-term process, not only a goal, and is not only limited to preserving ecological balance but also involves taking care of economic development, taking account of social aspects.

In this context, spatial planning or spatial management planning is of particular importance. Spatial planning, being an interdisciplinary activity, is an institutional and technical form for managing the spatial dimension of sustainability, which requires protection of space and the preservation of the quality of the environment, based on the assessment of development opportunities within the context of retaining the specificity of space. In doing so, the purpose of space/area is determined, as well as conditions for the development of certain activities and their spatial distribution, conditions for improvement and urban renewal of built-up areas, and conditions for the implementation of planned interventions in space.

The term planning refers to planned management, use of land and protection of space as a valuable and limited resource, which is ensured by the implementation of planning documents based on a holistic approach to spatial planning and the principles of sustainable human development.

A holistic approach to spatial planning and spatial regulation includes: researching, verifying, and evaluating the possibility of spatial interventions; use, protection and space management method; monitoring the situation in space, and drafting and adopting planning documents; implementation and monitoring of the implementation of planning documents.

Space management is achieved based on prepared and adopted planning documents as the basic legal management instruments. The planning documents determine the proper organization, use of land and its purpose, and measures and guidelines for regulation and protection of space, which are based on the adopted land use policy, development strategies and programs, infrastructure development plans and all other plans and programs relevant for spatial development planning. The procedure for preparing, drafting and adopting planning documents at all levels of spatial planning is prescribed by the Directive on a single methodology for drafting planning documents.

Depending on the space they intend to regulate, and the level of detail, planning documents can be: development plans and detailed planning documents. Development plans are strategic long-term planning documents that define the basic principles of spatial planning, the goals of spatial development, and the protection, use and purpose of space. They are designed for a period of 10 to 20 years. These include spatial plans (master plans) (of the Federation BiH, cantons, areas of special features and cities/municipalities), and urban plans. Detailed planning documents are technical and regulatory planning documents that regulate the use of space, its development and regulation. They are developed based on the obligation laid down in the development plans for a period of 5 - 10 years. These include zoning plans, regulatory plans and town planning projects.

Therefore, spatial planning i.e. development of planning documents at all levels is certainly a key factor in any development. Planning documents of different planning levels must be mutually consistent. The preparation of planning documents, especially the spatial plan as the core long-term strategic planning document, is a complex task based on the principles of scientific achievements in the area of urbanism and spatial planning, the achieved standards in this area and sustainable development, all in compliance with the applicable legislation.

A spatial plan is a synthesis document that contains the achieved realizations of space and generates its rational use, and whose settings are intended to ensure the economic and social development of the area it is intended to regulate, with proper use and purposeful management of resources while taking account of the land protection in space and its ecological, production and other functions. The spatial plan defines the basic principles of land planning, the goals of spatial development, and the protection, use and purpose of land, and in particular: the basic land use such as agriculture, forestry, artificial, water bodies, etc. Special importance is given to the content of urban and rural areas from the aspect of building regime, the establishment of infrastructure systems, etc. In doing so, the conditions of using, building, regulating and protecting space are determined. The deposits of mineral and other raw materials are spatially defined, the possibility of their use is planned as well as measures to protect the environment, cultural and historical heritage, and conditions under which these resources will be used. For the purpose of building and regulating the space, the obligation to prepare detailed planning documents for smaller spatial units are defined.

Spatial planning, as an expert synthesizing discipline, is based on the results of research in a number of specialist fields, as the evaluation of space as sustainable development, resource requires a multi-criteria approach. For this purpose, whenever lacking appropriate information for certain areas of particular relevance for development planning, research and development of specific specialist studies, study materials, offprints, and expertise studies are carried out, all to solve some specific problems in space in order to make informed decisions on the use of space in the planned period. Thus, for example, the development of the Spatial plan requires the development of the following studies: Natural sources and conditions, Settlement System, Transport, Water Management, Energy, Valuation and suitability of space for spatial development, Natural and historic values, Environmental protection and sustainable development. One of the basic and most relevant ones is the Land use study and map.

3.7. Land Use Value As A Factor Of Sustainable Land Management

The map of the land use value of an area, being a study result, is the basic map or the starting point for planning the basic types of land use in planning documents, since it addresses agricultural land that must be legally protected.

The main objective of the Land Use Study is to prepare a thematic database and map of land use value, as well as to examine and analyze the area of a municipality or canton using the GIS system and *remote sensing* sources of information (satellite and ortho-photo images). The aim is to establish the balances of land use, identify certain forms of land damage, perform valorization through soil quality rating, and analyze the pedological characteristics of certain soil types by opening pedological profiles and drilling probe holes in the field, sampling soil in the field, and analyzing them in the laboratory. All surveys are adapted and presented on maps of scale 1:10000 at the local level and 1:25000 at the cantonal level.

The study highlights the characteristics of an area and the importance of planning the use of land resources and provides recommendations and guidelines for sustainable land use.

The study shall determine:

- Condition of land cover/land use,
- Land quality/bonity classes,
- Agricultural land agro-zones from the aspect of agro-economic potential, and the possibility of their use for a specific agricultural production,
- The parameters according to which the land use value should be the basis for determining the exchange value of land (agricultural and forest),
- Limiting factors for cost-effective and rational forms of agricultural production,
- Review of the applicable legislation.

Pursuant to Article 73 of the *Directive on a single methodology for the development of planning documents* (Federation of BiH Official Gazette, no. 63/04 and 50/07), all cartographic representations in electronic form shall be prepared in a scale. In order for the maps to be of good quality and used for the multi-criteria valorization of space, it is necessary to make them using the GIS software and the set methodology. This kind of approach allows easier preparation of planning documents required by the law, thus allowing easier valorization of the space and making decisions on its use and protection.

In accordance with the applicable legislation (Law on Agricultural Land, Federation of BiH Official Gazette, no. 52/09), the land use in the spatial plans is determined based on the map of agricultural land use value, as follows: land from I to IV bonity (soil quality) class are defined as solely agricultural; the land of V and VI bonity class is defined as agricultural and exceptionally as land for other purposes; the land of VII and VIII bonity class is defined as land that will also be used for other purposes, as required.

According to the Instruction on expert criteria for the classification of soil into bonity (quality) classes (Federation of BiH Official Gazette, no. 78/09), soils are classified into eight bonity classes, with class I representing the best quality soils, and class VIII the lowest quality ones.

In the process of soil categorization (rating), the following important properties are considered:

a) Type of soil and its properties: morphological (depth, compaction, skeletalness, plasticity, etc.); physical (texture, structure, permeability, etc.); chemical (pH, humus content, the content of $CaCO_3$ etc.),

b) General characteristics of the terrain: relief features, exposure, inclination, the position of the plot, rockiness, etc.; hydrological conditions (flooding, drainage, irrigation, etc.).

The term soil categorization (rating) implies the relative assessment of soil quality and its productive capacity. Values are expressed in points from 1 to 100. Legal land classification relies on the international categorization system (*Land capability classification*) adapted to the conditions of the environment in which it is applied.

The established rating categories of agricultural land, according to its use value, are classified into two groups: land suitable for cultivation (I-IV bonity class) and land with limited use – generally less suitable or unsuitable for cultivation (V-VIII bonity class).

The I bonity class (90-100 points) includes deep and very deep soils, over 120 cm deep, of loamy composition, medium permeability, well drained, neutral reaction, with groundwater table under 120 cm, in flat relief with a slope of up to 3%, protected from flooding, with no skeleton or rockiness, with a vegetation period of more than 240 days, with a favorable SET/PET ratio of 0.8, light and suitable for mechanized cultivation and irrigation.

The II bonity class (80-90 points) includes deep soils, over 90 cm, of loamy and clay composition, good to medium permeability, well and moderately drained, neutral and slightly acidic reaction, with groundwater table under 100 cm, in a flat relief with a slight inclination of up to 8%, exposed to very low surface erosion as well as to very rare and transient flooding, light and medium-heavy, suitable for mechanized cultivation and irrigation.

The III bonity class (60-80 points) includes medium-deep and deep soils, over 60 cm, of loamy and clayey texture, good to low permeability, good to incomplete drainage, with slightly alkaline to medium acidic reaction, groundwater table below 80 cm, in flatland and slopes of up to 16% (exposed to mild forms of erosion when on a slope), exposed to occasional and transient flooding, easy to difficult for cultivation with some limitations in terms of mechanized cultivation, require erosion and flood control measures.

The IV bonity class (40-60 points) includes soils of the medium depth of 40-60 cm, of loamy and clayey texture having up to 30% skeleton, and up to 10% clay in sandy ones, alkaline to very acidic reaction, less drained, permeable to more difficult to permeate, with groundwater, transient overwetting, in the flatland and up to 30% slope (on slope – exposed to all forms of erosion), in the flatland they are medium deep and with regular short-term flooding, require erosion and flood control measures as well as land reclamation measures. Of that:

IVa bonity subclass includes soils that are well to poorly drained, less skeletal up to 10% on flat relief, predominantly flooded and under the impact of stagnant water; and bonity subclass IVb includes less drained soils on sloped relief with up to 30% inclination, medium skeletal with up to 30% skeleton.

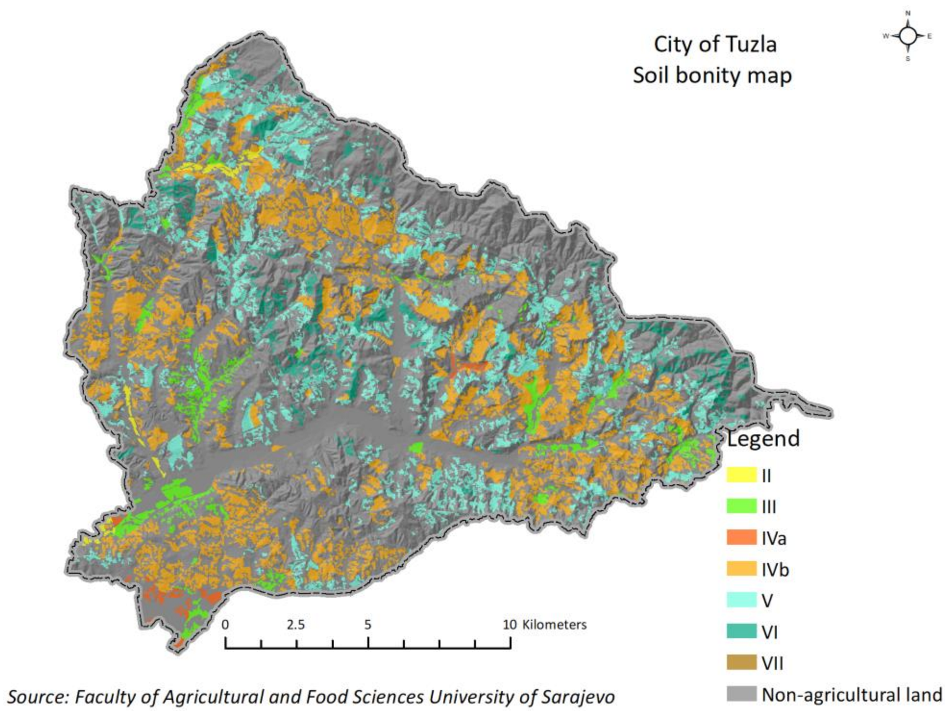
The V bonity class (30-40 points) consists of soils that are medium-deep and shallow, under 40 cm, containing up to 50% skeleticparticles, of extreme acidic reaction, medium-term overwetting, regular and long-lasting floods, in the flatland and on a slope of up to 45% (on a slope – exposed to all forms of superficial and slight gully erosion), require erosion control measures and land reclamation measures.

The VI bonity class (20-30 points) is characterized by mostly shallow soils, containing up to 70% skeleton, long-lasting waterlogging, eugleic to the surface, with regular and lasting floods, in the flatland and on a slope of up to 45% (on a slope – exposed to all forms of superficial and medium gully erosion), alkaline to very acidic reaction, medium damaged and degraded, with long-term overwetting with a high groundwater table, requiring erosion and flood control measures.

The VII bonity class (10-20 points) includes soils majority of which are very shallow, containing over 70% skeleton, on a slope of 60% (on a slope – threatened by severe gully erosion), very much damaged and degraded, alkaline to extremely acidic, requiring erosion control measures, and can only be used as meadows, pastures and forests.

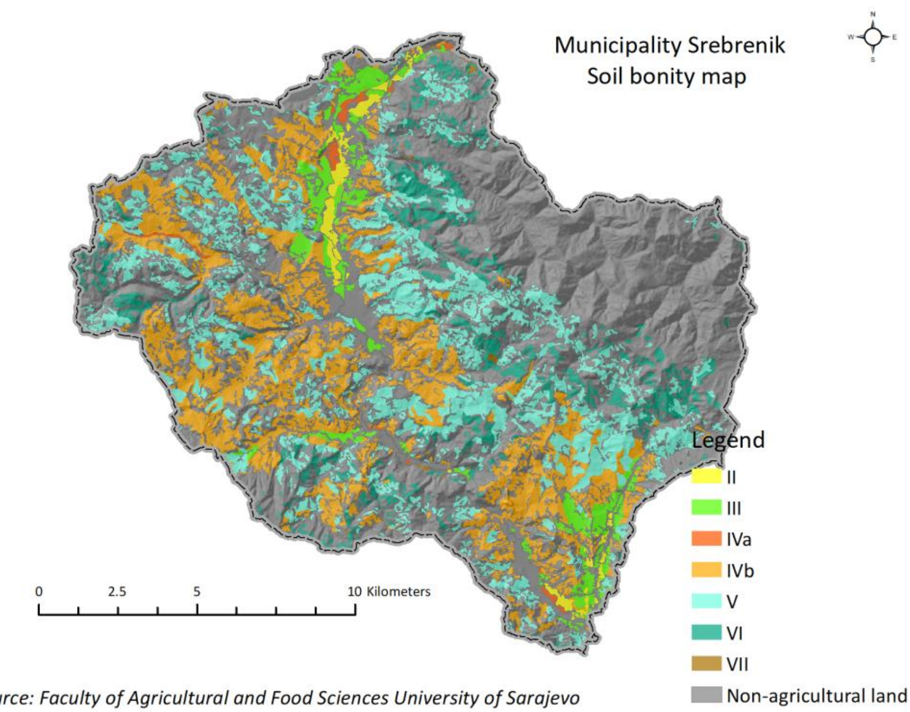
The VIII bonity class (up to 10 points) includes urban zones, mineral exploitation sites, roads, water reservoirs, and very shallow soils containing up to 90% skeleton, on slopes exceeding 65%, threatened by the most severe forms of erosion, used as pastures.

FIGURE 9. *Land use map developed for the area of nine municipalities in Tuzla Canton (Tuzla, Srebrenik, Gradačac, Kalesija, Banovići, Gračanica, Živinice, Kladanj, Sapna)*



Source: Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 10. *Soil bonity map for the City of Tuzla*

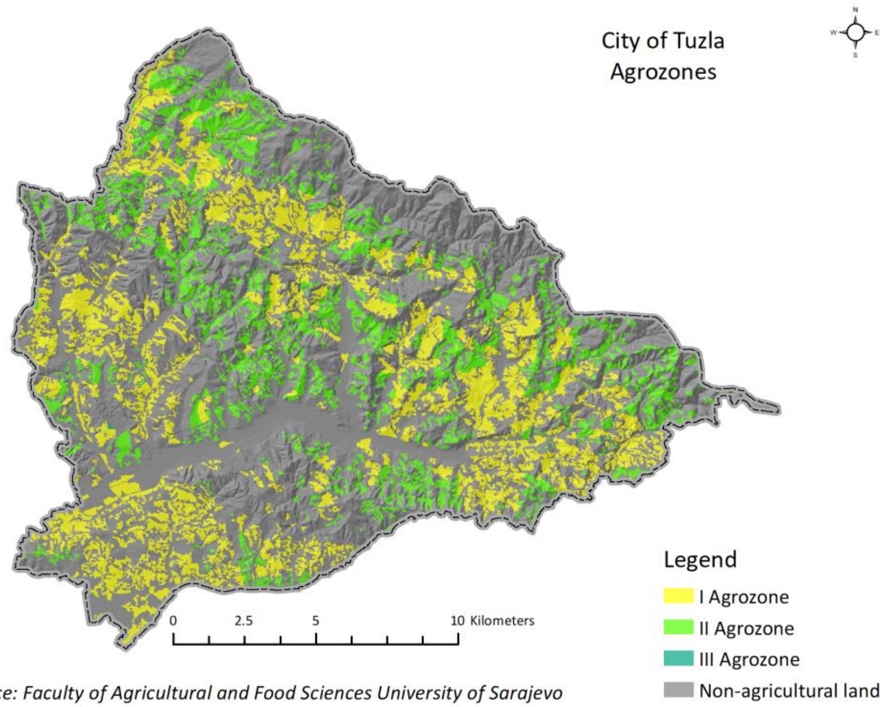


Source: Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 11. *Soil bonity map for the area of Municipality of Srebrenik*

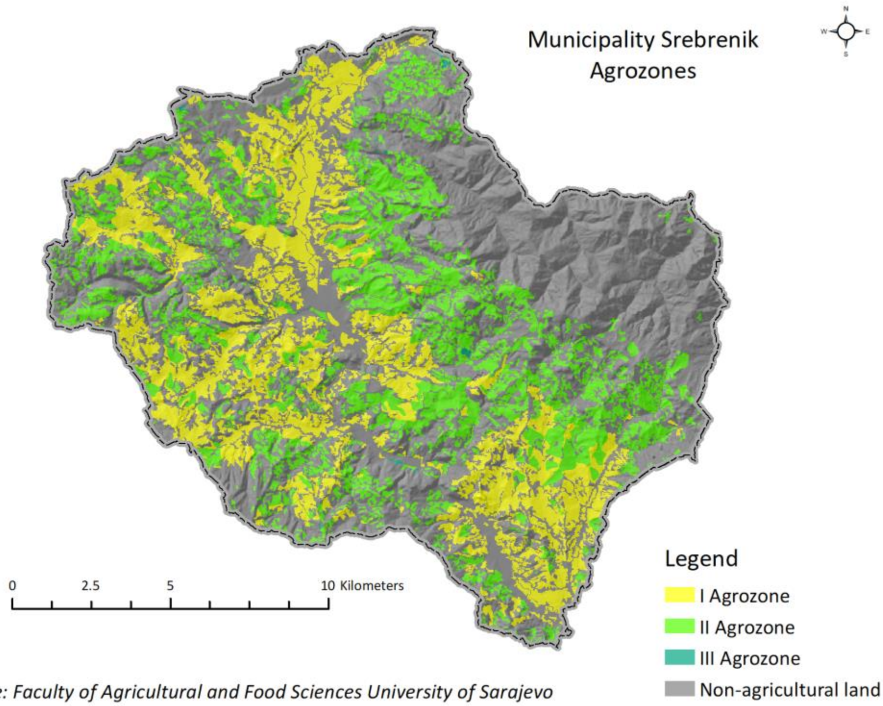
The use value of agricultural land, according to the approved agropedological categorization, is divided into three agro-zones:

- **I agro-zone** (I-IV bonity class) land solely intended for agriculture;
- **II agro-zone** (V-VI bonity class) land that can be used for construction purposes after the conversion of use;
- **III agro-zone** (VII-VIII bonity class) land that has little or no use for agriculture.



Source: Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 12. *Agrozones of the City of Tuzla*



Source: Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 13. *Agrozones of the Municipality of Srebrenik*

All data treated by the land use value map should be part of a single information system in in the area of spatial planning of cantons and municipalities (the establishment of which is a legal requirement), and is therefore very important to have the appropriate and single methodology for map development.

It often happens that, at almost all levels from the municipality to the Federation, terms and data on the soil bonity class and cadastral land class are confused. Soil bonity class is determined based on natural soil conditions (morphological, hydrological and physical, and chemical properties), climate, and position (inclination, exposure, altitude, rockiness, lithology, number of vegetation period days, etc.). Cadastral class of land is determined on the basis of natural conditions used to determine the bonity classes, but in relation to the method of use (plough-field, garden, orchard, vineyard, meadow, pasture, etc.) and economic conditions (the distance of land from markets and consumer centers, road communications, the position of the land plot in relation to the settlement, accessibility of the plot, etc.).

There is a need to explain in more detail that the bonity class determines the degree of suitability of land for agricultural production regardless of its use, whereas the cadastral classification determines the use method and production capacity of the cadastral plot taking into account the natural and economic conditions that the cadastral parcel has for agricultural production, which is the basis for tax policy.

Specifically, in the Federation of Bosnia and Herzegovina, the bonity classes, in spatial plans and other documents, and on the basis of land use value maps, are classified into three agro-zones, where agro-zone I (I-IV bonity class) is determined solely as agricultural land; agro-zone II (V and VI bonity class) as agricultural land, and exceptionally as land for non-agricultural purposes; and agro-zone III (VII and VIII bonity class) that can be used for other purposes as needed.

Thus, the bonity classes are used to classify land in agro-zones, based on which, according to the land use map, land can be planned for specific purposes or land use conversion (either permanent or temporary one). Based on the bonity classes, the spatial plan determines whether and how the agricultural land use can be converted, and based on the cadastral land class the fee for land conversion can be calculated by calculating the cadastral income.

Therefore, cadastral classification cannot serve as a basis for the conversion of land use, since the current land use method does not reflect the natural potential of the land. For example, the most fertile land for growing the most important crops does not necessarily have to be used for this purpose at a given time but can be converted into meadows and pastures, with the tax base being smaller under these circumstances.

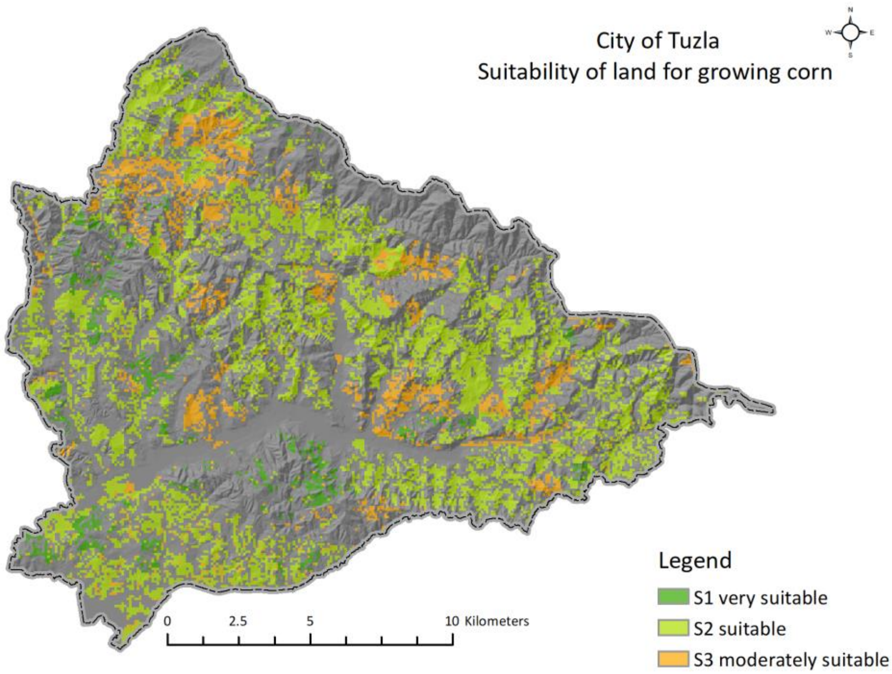
The collected funds go to a special, assigned fund that can be used to develop the basics of programs, protection projects, use and regulation of agricultural land, to produce maps of land use, to establish a land information system, to implement measures in the field, to develop strategies, management programs, etc., and can also serve as a fund for financing SLM measures.

Agro – ecological zoning

A very important addition to the land use map is agro – ecological zoning, which is a set of maps of land suitability for growing specific agricultural crops. Agro – ecological zoning indicates the advantages and constraints typical of soil types in relation to the requirements of a particular crop to be grown.

This type of assessment and analysis facilitates the definition and implementation of measures that should mitigate or completely eliminate certain limitations, or help decide to abandon certain plans if the measures lack technical or economic justification.

During the analysis, this type of approach enables a farmer or financier who wants to invest in a particular agricultural production, to more objectively evaluate the choice and type of production or the need to apply certain agro-technical measures that can improve the soil condition for a particular crop (Ljuša *et al*., 2015). In this way, the land value can be assessed from the aspect of different sectors (urbanism, agriculture, etc.) and their needs, and direct development towards the protection and sustainable use of land and land areas.



Source: Faculty of Agricultural and Food Sciences University of Sarajevo

FIGURE 14. *Suitability of land for growing corn in the area of the City of Tuzla*

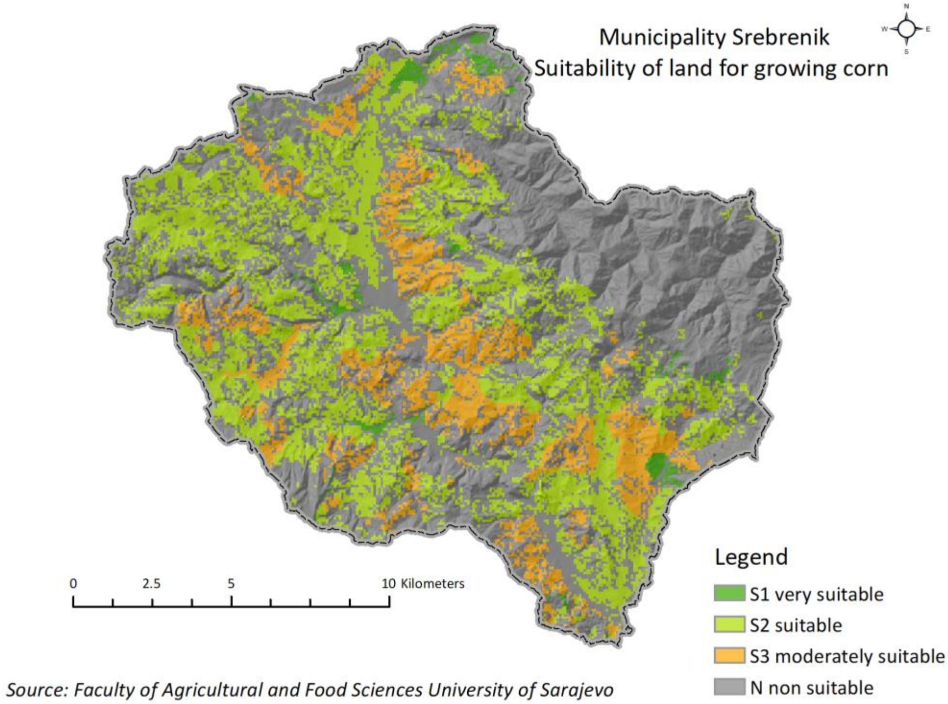


FIGURE 15. *Suitability of land for growing corn in the area of the Municipality of Srebrenik*

3.8. Overview Of Available Methods For Removing Targeted Pollutants

Bosnia and Herzegovina, especially its central part (mining zone), is characterized by two types of deposited materials: ash and slag from four thermal power plants existing in Bosnia and Herzegovina; and disposal sites for overburden from surface mining that is deposited on the surface.

In the case of ash and slag dumps, remediation procedures may be different, most often reduced to covering the surface with soil or some geological material to prevent aeolian erosion. As a next step, the most appropriate way of the remediation of these areas is to apply some of the remediation measures provided that such areas will be used for agricultural production. The ash and slag disposal site Drežnik is an example where agricultural crops are grown and used in human and animal nutrition without prior detailed analysis and monitoring.

FIGURE 16. *Indirect recultivation – covering the deposited ash and slag with soil at TP Tuzla (Photo: H. Čustović)*

The problem of the disposal of overburden from mines is of a different character. These are mainly geological substrates of different origin from deep layers, whereby the process of their wear may be faster or slower. The recultivability of geological substrates on the surface also determines the application of measures for their recultivation. If the wear process is slow, it is advisable to put a soil layer of about 50 cm on flat areas, and use it in agricultural production without any restrictions. This type of recultivation is called indirect. However, on the slopes of disposal sites, the so-called direct recultivation or forest recultivation is applied, taking care of regulating the slopes to prevent erosion processes. The success of this type of recultivation can be seen in the example of the Višća – Đurđevik disposal site, as well as disposal sites in the area of Municipality of Banovići.

FIGURE 17. *Example of successful recultivation of the overburden disposal site in Municipality of Banovići (Photo: H. Čustović)*

FIGURE 18. *Banovići, overburden from mine before recultivation (Photo: H. Čustović)*

FIGURE 19. *Banovići, overburden from mine after recultivation (Photo: H. Čustović)*

If in the soil/substrate tested the concentrations of toxic metals are above the limit values prescribed by the „Rulebook on the determination of allowed quantities of harmful and hazardous substances in soil and methods of testing“ (Federation of BiH Official Gazette, no. 72/09), that soil/substrate can be considered contaminated, which means that agricultural production should not be carried out without prior remedial action. The choice of remediation measure depends primarily on the properties of soil/substrate and the degree of its contamination with heavy metals, but irrespective of the choice, the remediation measure applied must be technically appropriate, economically viable, and most importantly, environmentally friendly.

Pierzynski *et al*. (1994) classified contaminated land management into three categories: reducing the concentration of total pollution to an acceptable level; physical/biological/mechanical isolation of pollution to prevent further reaction of soil with the environment; and, reducing the bioavailability of organic and inorganic pollution.

The term to remediate/reintegrate means to repair or eliminate. Therefore, remediation/reintegration could be defined as *treating disposal sites in such a way that they become part of or even integrate with the surrounding environment/landscape and, ideally, no longer be identifiable as disposal sites*.

Remediation/reintegration also means that major threats – such as the spread of dust due to aeolian erosion, which can severely worsen living conditions – have been stopped. This term also shows that treatment solutions can aim to restore agricultural potentials.

Different remediation technologies can be implemented on contaminated soil, while the choice of technology largely depends on (Kisić, 2012): type of pollution, spatial scope of pollution (surface, volume, and place of pollution – the proximity of surface/groundwaters), type of soil (pH reaction, organic matter content, texture, especially the share and type of clay), time period of exposure to potential pollution, future use, defined legal framework of a particular country regarding the required degree of remediation.

Some of the most important measures of remediation of contaminated soils are as follows:

- Phytoextraction or planting of plants that accumulate heavy metals from the soil (nettle, spinach, etc.),

- Soil treatment with zeolite, a naturally occurring volcanic rock mineral having the ability to inactivate heavy metals,
- Calcification or adding Ca to the soil in order to increase the pH level and reduce the mobility of heavy metals therein.

However, solutions relating to the remediation of ash disposal sites depends on the specific situation, meaning that local factors are crucial for decision-making. Decision support tools are presented in the form of a simple four-step framework (Figure 20.)[24], that is flexible and can be tailored to the requirements of the problem in question and the level of knowledge available.

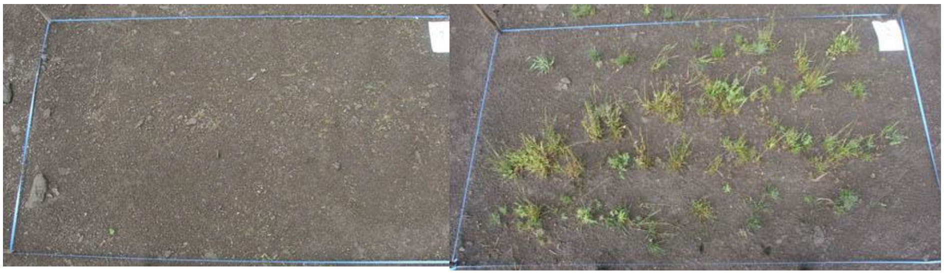
The treatment solutions proposed under the FP6 RECOAL project, where some experimental research focusing on the reintegration of disposal sites and mitigation of environmental impact has been carried out at the disposal sites Drežnik and Divkovići in Tuzla, proved to be appropriate, technologically simple and inexpensive. Table 8. provides a comprehensive list of remediation methods (but it does not contain all possible methods).

[24] Project FP6 RECOL (Reintegration of coal ash disposal sites and mitigation of pollution in the West Balkan area), 2005-2007, Drežnik and Divkovići-Tuzla. Wenzel,W., Fitz,W., Dellantonio,A., Kupusović,T., Čustović,H., Jabučar,D., Zerem,N., Haznadarević,M., Markovic,M., Babić,M., Lazic,S., Šipka,M., Bašić,F., Zgorelec,Ž., Kisić,I., Hüttl,R., Repmann,F., Schneider,U., Grünewald,H., Tabbush,P., Carter,C., Castan-Broto,V., Edwards,D., Džindo,M., Pirić,M., Hajdarević,S., 2008: Priručnik o tretmanu odlagališta pepela, Vienna.

FIGURE 20. *Decision-making support tools (adapted)*

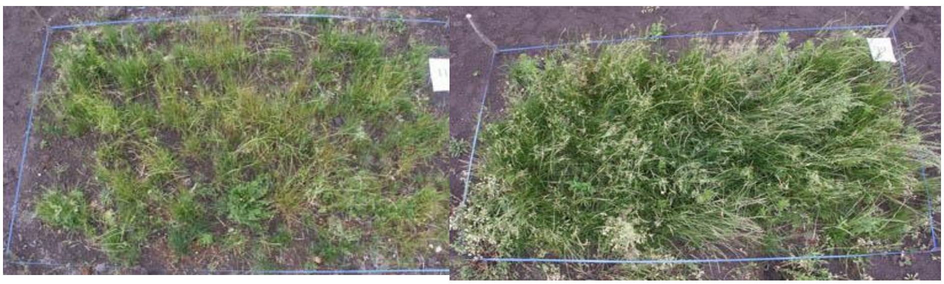
The USA EPA has defined phytoremediation as a technology using plants and their rhizospheric microorganisms to remove, degrade or retain harmful chemicals in soil, groundwater, surface water, and the atmosphere. The advantage of phytoremediation is the fact that it is the most environmentally friendly method as it uses plants. It is economically viable, as it is one of the most inexpensive technologies. It can be used for remediation of large soil surfaces (Kisić, 2012).

As part of the FP6 RECOAL project research, grass growth was tested at the disposal site Divkovići. Figure 21. shows the growth of a specific mixture of grass, consisting mainly of red fescue (*Festuca rubra*) and sheep fescue (*Festuca ovina*) grown in different treatments (without the application of compost, to the application of maximum amount).



Plot 7: Control plot – no treatment

Plot 2: 1 liter of compost per 1 m^2 applied



Plot 11: 10 liters of compost per 1 m^2 applied

Plot 49: 20 liters of compost per 1 m^2 applied

FIGURE 21. *Grass growth in various treatments at the disposal site Divkovići I, carried out under the RECOAL project (Photo: F. Repmann)*

The application of compost not only sustained grass growth, but also increased biomass production and soil coverage. Accordingly, the application of 10 – 20 l/m^2 of compost is likely to be sufficient to achieve grass coverage sufficient to prevent ash erosion. Additionally, compost improved the fertility of the ash substrate when it comes to N, P and K and microbiological activity in the treated ash. However, although the uptake of pollutants by the plants in treated ash decreased when a comparison was made with untreated ash, some of the pollutants were present in grass grown on treated ash at concentrations higher than normal.

This grass is therefore not considered suitable for livestock feeding, and its use for such purposes should not be encouraged in order to minimize the risk of transmission to the food chain, especially with regard to direct ash intake by ingestion during grazing.

As part of the RECOAL's field experiments, it was established that the addition of compost to ash was more cost-effective than the application of soil. However, this type of supplement to ash is not adequate for all types of cover and is actually only considered suitable for grass. For this reason, the application of this supplement may not meet the expectations of the local population when it comes to remediation results, especially in terms of landscape features, benefits and safety of use that would result from the application of a thick layer of soil.

Field experiments were conducted at Drežnik and Divkovići in order to assess the safety of maintaining the ash disposal site under realistic conditions. Five different types of crops were grown at Drežnik: potato *(Solanum tuberosum)*, bean *(Fasoelus vulgaris)*, maize *(Zea mays)*, barley *(Hordeum sativum)* and alfalfa *(Medicago sativa)*, and their growth was monitored on a daily basis. The results indicate that arsenic and boron, and in some cases cadmium, pose risk when it comes to growing plants for human consumption.

At Divkovići, the cultivation was performed directly on the ash, after the compost was added. Economic analyzes have shown that agricultural crops such as winter wheat, barley and oat are not profitable, but could form part of agricultural practice. The establishment of pastures, on the other hand, might be economically viable, but grass/fodder should be checked for the presence of pollutants (initial results indicate a high risk of pollution). The application of good quality soil (unpolluted soil) and compost on disposal sites can reduce the risk of contamination. In addition, grass could be grown very quickly, which would stabilize the cover and improve landscape features.

When using land, testing soil, and applying layers of different soil types, it has been shown that if ash disposal sites were to be used for agricultural purposes or as pastures for the next 20 years and more, there is a high risk of the transfer of pollutants to the food chain. Long-term testing is required as well as the acceptable thickness of the applied quality soil if there is an extremely strong desire to use ash disposal sites for this purpose. Temporarily, it is advisable to plant crops that can be planted shallowly, i.e. on a thin layer of soil, and do not require cultivation or deep tillage.

Alternatively, the application of ash supplements (unpolluted organic matters) can help in establishing vegetation cover in a very short time, to prevent the dispersion of coal ash.

Windbreaks (shelterbelts) are an effective method of preventing dust dispersion from ash disposal sites. The dominant tree species in the areas surrounding disposal sites are willow, poplar, maple, beech, alder wood, hazelnut, hornbeam, elderberry, ash, and wild chestnut. The use of indigenous tree species in windbreaks would contribute to the formation of a more stable barrier (species are used in local biotic and abiotic conditions), and the preservation/enhancement of local ecosystems. Considering soil characteristics, the RECOAL project recommends the use of poplar *(Populus alba)* and hazelnut *(Corylus Avellana)* seedlings. Poplar is a tree that grows extremely fast, reaching a height of 25 m in a relatively short time. Hazelnut can supplement the natural barrier consisting of poplar, by filling the space under the poplar canopy height. Acacia, as a fast-growing species, is also very suitable.

Afforestation of disposal sites would initially require large expenditures, but it would be an extremely effective and multifunctional solution for the long-term well-being of the local population and ecosystems. For example, afforestation with poplar would have additional benefits such as logging and firewood production. Land under forest (including pastures) and belts of trees can dramatically improve the landscape, not only by stopping ash dispersion but also by providing opportunities for more attractive and healthier land use.

All different uses, including shelterbelts and land under forest (logging and firewood production, recreation, and the creation of a natural environment), can enhance the local population's relationship with the area itself.

TABLE 8. *Overview of available methods for the removal of targeted pollutants*

REMEDIATION	DESCRIPTION	ADVANTAGES	DISADVANTAGES	MEDIUM	GOAL
GENERAL TREATMENTS					
Physical barriers	A canal filled with materials such as bentonite, which would retain water and slow down the flow of water	Adaptability	Long-term degradation	Land and water	All
Passive/reactive treatment walls	Underground structures with fill that reacts with pollutants to retain or deposit them	Continuous land use is provided	Walls require maintenance	Land and water	Most organic and inorganic substances
BIOLOGICAL IN SITU TREATMENT					
Bioremediation/ Biodegradation	Use of fungi, bacteria and other germs to degrade pollutants	No major maintenance required, use of natural processes	Organisms specialized in certain types of pollutants and conditions	Land and water	Fuel; volatile organic compounds
Phytoremediation	Phytoextraction uses plants for taking pollutants from the soil. The same process for water remediation is called „rhyzofiltration“ (use of water troughs to facilitate absorption of pollutants). Phytoremediation processes using plant enzymes are also available.	A relatively inexpensive treatment, the level of acceptance by society is usually quite good	It is effective only in the case of surface pollutants, the problem of accumulation of pollutants in plants	Land and water	Fuel; volatile organic compounds; some metals (depending on the plants used)

Natural pollution mitigation	Using natural processes to stabilize pollutants or transform them into less toxic compounds/elements.	No major maintenance required, low cost	Slow process; requires monitoring of effectiveness	Water	Fuel; volatile organic compounds
Soil treatment/ Bioventing	Use of aeration or ploughing to stimulate biological activity and degradation, and improve physical soil properties	A simple measure	Limited results	Land	Polycyclic aromatic hydrocarbons, coal waste, some metals
PHYSICAL/CHEMICAL IN SITU TREATMENT					
Chemical oxidation/reduction	Adding chemical oxidants such as hydrogen peroxide, potassium permanganate, ozone and dissolved oxygen	Stabilization/degradation of pollutants	Stabilization or degradation is not always complete	Land and water	Metals
Electrokinetic separation	Application of low-intensity direct current, which drives live species to move towards ceramic electrodes	Used in saturated soil with low water permeability	By-products and side effects	Land	Heavy metals, polar organic substances
Soil washing	The solution is injected into the soil to facilitate the extraction of pollutants	Low cost	Limited success / may affect the flow of groundwater	Land	Volatile organic substances and inorganic substances
Solidification/stabilization	Binding material (cement, chemical solidifiers) that physically immobilizes pollutants can also be used ex-situ	Low cost, easily available	Future responsibilities	Land	Inorganic compounds; radionuclides

Thermal treatment	Heat is used to volatilize pollutants and facilitate their extraction	Effective method, destruction of pollutants	High cost	Land and water	Organic pollutants
Air-injection	Volatilization of pollutants is done by injecting air into the water	Long-term solution	An approach that is difficult to apply	Water	Fuel, inorganic compounds
BIOLOGICAL EX SITU TREATMENT (IMPLIES EXCAVATION)					
Bio - piles	Polluted soil is mixed with additives in the deposits into which the air is injected	Short-term process, natural decomposition	Cost	Land	Volatile organic compounds; certain specific materials
Composting	Adding organic matter to enhance carbon/nitrogen balance and boost microbial activity	A simple process	Space cost, the release of volatile organic compounds	Land	Polycyclic aromatic hydrocarbons
Biological treatment with water and ash mixture	Making a mixture of water and ash to deposit pollutants and facilitate microbial decomposition	Short to long-term treatment	Difficulties and costs associated with manipulation	Land	Organic and inorganic compounds
Bioreactors	The circulation of water facilitates the reaction between pollutants and microorganisms	A relatively economical method	Slow process	Water	Volatile organic compounds; PCBs
Artificial wetlands	Wetland facilitates the deposition of pollutants and their stabilization; it can also be done in situ.	Natural process, relatively stable	Long-term responsibility	Water	Inorganic compounds, especially metals

PHYSICAL EX SITU TREATMENT (IMPLIES EXCAVATION)					
Chemical extraction	Extraction of pollutants using acids and solvents	Concentration of pollutants	High cost; toxic solvents may replace the original pollutants	Land	Heavy metals; non-metals, organic compounds
Chemical oxidation / reduction	Chemical oxidants (e.g. hydrogen peroxide, potassium permanganate, ozone and dissolved oxygen) are used to convert pollutants into less aggressive forms	Quick and lasting conversion	The process may be incomplete	Land	Heavy metals, semimetals
Dehalogenation	Removal of halogen groups from chemicals, converting pollutants into non-toxic salts and volatilizing the pollutant	Destruction of pollutant	Small volume treatment, high cost	Land	Halogenated volatile organic compounds, PCBs, dioxins
Separation	Use of physical or chemical methods to concentrate and remove pollutants	May allow re-use	Method availability, disposal of separated pollutants	Land and water	Organic and inorganic compounds
Soil washing	The separated land is washed using water and additives	The amount of polluted soil reduces	Subsequent treatment of the solutions used for washing	Land	Fuel, heavy metals
Solvent extraction	The solvent is added to the soil, which removes pollutants and facilitates their separation	The amount of polluted soil reduces	Removal of solvents, treatment before and after	Land	Organic waste and waste in the form of oil

Thermal ex-situ treatment	Incineration, pyrolysis (incineration without oxygen), and thermal desorption (volatilization of heat) are the methods used to separate and destroy pollutants	Effective removal and destruction	Controlled systems, expensive method, difficulties with the implementation	Land	Organic compounds, coal ash, coal waste
Adsorption / absorption	Sorbents are used to concentrate chemicals	Easy application	Disposal of sorbents	Water	Selected inorganic pollutants
Adding water to the air	Water is sprayed into the air, thus facilitating the removal of pollutants	Relatively low cost	Additional treatment is required	Water	Volatile organic compounds
Filtration	Water flows through the medium with pores, removing particulate matter; the method can also be used in situ	An option for pre-treatment	Additional treatment is required	Water	Suspended particulates
Pumping-out of groundwater	Removal of contaminated water from disposal site to prevent the formation of the pollution plume	Usual and well-known method	Water discharge	Water	Dissolved pollutants
Ion replacement	Ion exchange material (e.g. resin) replaces polluting ions with less aggressive ones	Mature technology	Resin and metal deposition	Water	Metals
Sedimentation / Flocculation	Additives are used that boost sedimentation of pollutants and facilitate their removal	Mature technology	Sediment deposition	Water	Metals; radionuclides
Reversible osmosis	Pollutants are removed by water passing through the membrane under pressure	Pollutant contents reduce	Expensive method	Water	Metals; radionuclides

RETENTION					
Disposal site overlaying	Establishing a layer over the disposal site that minimizes the interaction of pollutants with the ecosystem	Effectiveness is related to the material used; low cost	Long-term responsibility, leakage	Land	All
Disposal site overlaying alternatives / additives	Additives intended for the interaction with pollutants (e.g. correction of pH, conductivity, porosity), for stabilization and control	Simple project, low cost	Long-term responsibility	Land	All, on stable disposal sites
Ex-situ disposal	Soil is dug out and disposed on a site where the risk it poses is lower	'Fast and dirty" method	Transfer of pollutants to another location	Land	All
Geotechnical systems	Use of technical facilities to contain and reduce exposure to pollutants	'Fast and dirty" method	Long-term responsibility	Land	All
Control wells	Drilling techniques allowing access to groundwater	Access to chemicals	High cost, incompleteness	Water	All

Source: RECOAL, 2007

PRIORITIES IN THE RESTORATION OF THE DEGRADED LAND OF TUZLA CANTON (EXAMPLE)

Tuzla Canton – basic spatial features

Tuzla Canton is one of ten cantons in the Federation of Bosnia and Herzegovina, which covers the area of northeastern Bosnia and Herzegovina with a longitudinal backbone – the valley of the Spreča river and the mountains of Trebavac, Majevica, Ozren, Konjuh, Javorje and Javornik. The favorable combination of road and rail routes in the north-south and east-west directions is a result of the high development potential of the area. By its natural features and structure, the Tuzla Canton is a rather diverse and complex natural compound, which, because of its natural wealth, makes the backbone of the industrial development of Bosnia and Herzegovina.

The canton comprises thirteen municipalities: Tuzla, Srebrenik, Gradačac, Lukavac, Kalesija, Čelić, Banovići, Gračanica, Živinice, Kladanj, Doboj - East, Sapna and Teočak. The administrative and governance structures of the Tuzla Canton are located in Tuzla.

The area of Tuzla canton is 2,649 km^2 which is 5.17% of the territory of the state of Bosnia and Herzegovina. This area is home to 1/4 of the population of the Federation of Bosnia and Herzegovina (approximately 480,000 inhabitants), and is one of the most densely populated areas in Bosnia and Herzegovina, with a population density of 181 inhabitants per km^2. The largest concentration of population is in the City of Tuzla and the municipalities of Živinice and Lukavac, precisely in the areas richest in mineral resources but also with the highest level of limiting factors for spatial development.

Use and regulation of space (spatial indicators)

The basic mandatory planning document for the canton area that provides for planned management, land use and space protection, is the adopted 2005 – 2025 Spatial Plan of the Tuzla Canton area. The main purpose of the Tuzla Canton Spatial Plan is to ensure its economic and social development based on the principle of rational use and sustainable management of resources while protecting space and respecting the principles of human and sustainable development.

During the preparation of the Spatial Plan, very extensive research was carried out on the structure and natural characteristics of the Tuzla Canton area, on population movement, settlements' development, economy, and non-economic activities, as well as on all significant impact that economic development exerts in space.

In this way, a detailed insight was obtained into the structure of space use and the possibilities the space provides for future development. In this analysis, the goals of the spatial development of the Canton were defined and subsequently elaborated through the Spatial Plan by developing and adopting the projection of the spatial plan and development of the Canton.

A comprehensive analysis of the state of Canton's space in the previous period has shown that forestland with 49.72%, agricultural land with 32.38%, and construction land with 13.77% are the most represented in the land use structure. Other land areas with different purposes account for 4.13% of the Tuzla Canton area.

TABLE 9. *Balances of basic land uses in the Canton area*[25]

Use	Area (ha)	Structure (%)
Forest land	131,690.51	49.72
Agricultural land	85,755.47	32.38
Artificial (construction) (housing and economy)	36,498.50	13.77
Traffic areas	2,178	0.80
Quarries	363.89	0.14
Recreational areas	734.70	0.28
Airports and the land of special purpose	484.88	0.20
Disposal sites of slag and overburden	1,228.46	0.46
Degraded areas – planned recultivation	2,646.33	1.00
Technological waste disposal site (white sea)	69.02	0.03
Solid waste disposal sites	78.97	0.04
Water surfaces (reservoirs)	1,970.53	0.74
Watercourses	1,070.23	0.40

[25] Amendments to the Tuzla Canton Spatial Plan, 2018

As for other resources, the Canton area is rich in deposits of various types of coal and minerals, so most of the economic development and life is based on the exploitation and processing of these resources. Considering the importance of mineral resources for the development of the whole Tuzla Canton and the wider region, the spatial plan pays special attention to mineral deposits and provides an overview of identified reserves, exploitation fields, possibilities of using the land above underground mines and on surface mining areas, land reclamation, land protection, etc.

Tuzla Canton has considerable resources: mineral reserves and forest and agricultural land, but there is also a marked conflict between the exploitation of mineral deposits, the protection of quality land, and the development of populated areas. These are the reasons why spatial planning in the Canton area is given special importance.

Status of degraded land areas in the Tuzla Canton

Through the preparation of planning documents and continuous monitoring and analysis of the situation with space in the area of Tuzla canton, it was concluded that the space of the canton is burdened with many limiting factors for development such as:

- Large areas of land covered by approved exploitation fields of mineral resources (coal, salt, quartz sand, limestone), amounting to over 7.5% of the surface of the Canton;
- Large areas of degraded land resulting from ground and surface mining for mineral resources (coal, salt, quartz sand, limestone, etc.), accounting for 1.4%;
- Large areas under disposal sites of slag and ash, and technological waste, about 0.5% of the canton area;
- Large areas affected by unstable relief (approximately 13% of the land is susceptible to erosion and landslides) and landslides (approximately 5.8% of land area) which threaten both construction land and valuable agricultural land;
- Unregulated river flows of the Spreča and Tinja, which, being torrential watercourses, flood and endanger approximately 2.5% of the surface of Tuzla canton;

- Unresolved final disposal of waste and rehabilitation of existing landfills in the Canton area;
- Temporarily unusable land areas (suspected mine areas) accounting for more than 3% of the surface of the Canton, etc.

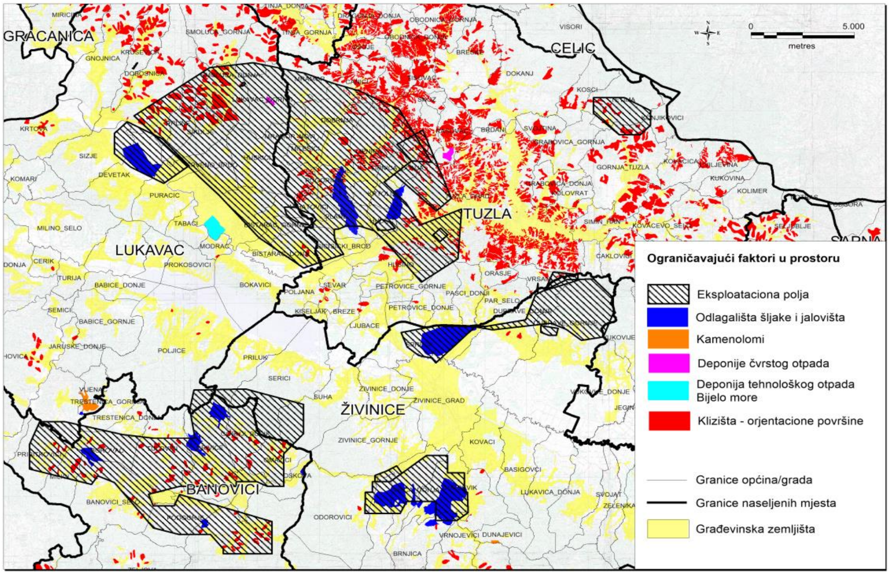


FIGURE 22. *Overview of the limiting factors for development in the central part of Tuzla Canton*

Limiting factors in space

Exploitation fields	Municipality/town boundaries
Disposal sites for slag and tailings	Boundaries of populated areas
Quarries	Building lands
Solid waste disposal sites	
Technological waste disposal site Bijelo more	
Landslides – approximate surfaces	

Many of the limiting factors in the Tuzla Canton overlap and impact largely on land degradation. Surface mining, industrialization and urbanization involve large areas of land, which causes conflicts between industrial development and mining on the one hand and the preservation of land quality on the other.

Table 10. provides an overview of land areas which, according to their use, are under the influence of land degradation, as well as land areas affected by land degradation processes.

TABLE 10. *Overview of land areas affecting or being affected by degradation processes*[26]

Land use and land degradation processes	Area (ha)	Structure (%)
Coal exploitation fields	18,592.44	7.1
Quartz sand exploitation fields	717.22	0.3
Rock salt exploitation fields	406.38	0.15
Limestone and diabase exploitation fields	405.38	0.15
Disposal site of slag, overburden and technological waste	1,228.46	0.5
Flood areas	6,740.96	2.5
Landslides – approximate surfaces	15,550.5	5.8
Suspected mine areas	8,470.61	3.2

Based on the generation of spatial data (GIS database of the Canton's Spatial Plan, studies of land use value, data of the Cantonal Administration of Civil Protection, ortho-photo imagery data from 2012, etc.), the state of the most endangered land areas in the Tuzla canton was determined. The central part of the Tuzla Canton including the city of Tuzla, and the Municipalities of Živinice, Banovići, and Lukavac, occupy an area of 110,823 hectares (about 42% of the Canton area), in which special attention must be paid to planning the recultivation of degraded land, given that this is a densely populated and urbanized area. Namely, in these municipalities, degraded land areas resulting from surface mining for mineral resources, especially coal and quartz sand, amount to 2,581.65 hectares, which is more than 98% of the total degraded land area in the Tuzla canton (2,646.33 hectares). The total area of closed and active slag and overburden disposal sites existing in these four municipalities amount to 1,228.46 hectares. In addition, landslides occupy as many as 5,599 hectares of the total area in question, which is 5% of the total area. The following table provides an overview of the situation of the most vulnerable municipalities/city of the Tuzla Canton, expressed in the area of degraded land, according to different forms of land degradation.

[26] Amendments to the Tuzla Canton Spatial Plan, 2018

TABLE 11. *Overview of the situation of the most vulnerable municipalities /towns in the Tuzla canton*

Form of degradation (ha)	Municipality/town Tuzla	Banovići	Živinice	Lukavac	Total (ha)
Degraded land areas resulting from surface mineral mining	150.32	512.78	692.35	1,226.2	2,581.65
Slag and overburden disposal sites	264.5	170.36	645.69	147.85	1,228.46
Quarries – existing ones		84.1	25.23	39.36	148.69
Solid waste landfills	21.05		21.25	10	52.3
Technological waste disposal sites (white sea)				69.02	69.02
Total (ha)	**435.82**	**767.24**	**1,384.52**	**1,492.41**	**4,079.47**
The share of degradation in the total land area of the municipality/town (%)	1.4	4.1	4.7	4.4	3.6
Landslides – approximate surfaces	4,104.28	364.8	105.72	1,024.72	5,599.51

Selection of priority areas for intervention

The inherited condition of different types of land use impacting on land degradation in the area of Tuzla Canton indicates the need for urgent implementation of remediation and recultivation measures, the dynamics of which must be pursued successively, depending on the need to resolve priority spatial issues, all with a view to implementing the adopted projection of spatial development for a specific timeline. Given that the planning documents identify, to a large extent, problems in the area of Tuzla canton, priorities for the reconstruction of damaged and degraded land areas by any of the technical and biological methods (recultivation, remediation, rehabilitation, etc.) can be clearly determined and projects nominated for implementation for each municipality.

When selecting priority areas for intervention in this case, account should be taken first and foremost of the nature and degree of land degradation, the population concentration, and the condition of the environment in these areas. Taking into account all previous criteria, the following figure shows marked areas with the highest degree of land degradation in the Tuzla Canton.

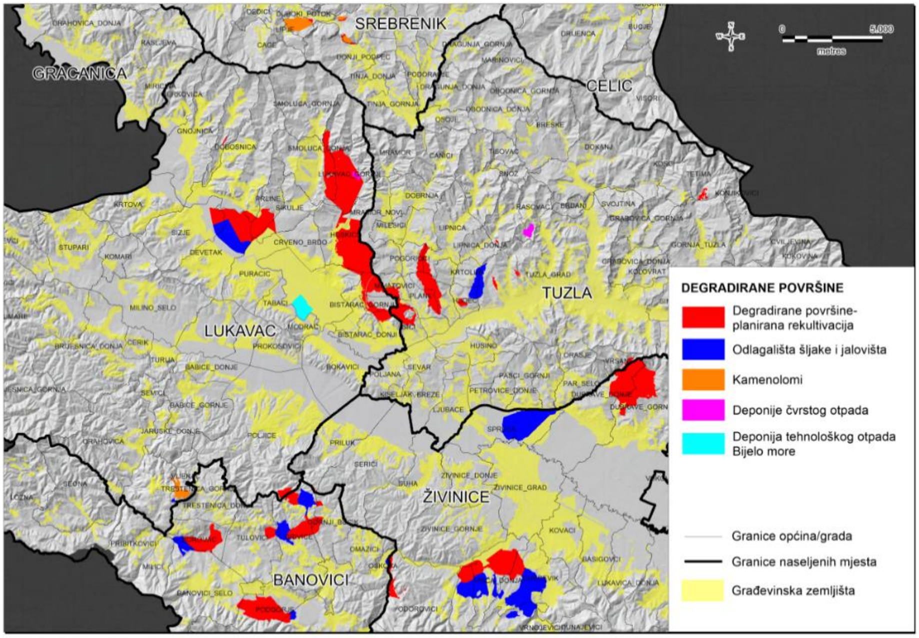


FIGURE 23. *Areas with the highest degree of land degradation in the Tuzla Canton*

Degraded areas

Degraded areas–planned recultivation

Disposal sites for slag and tailings

Quarries

Solid waste disposal sites

Technological waste disposal site Bijelo more

Municipality/town boundaries

Boundaries of populated areas

Building lands

The area along the border between the City of Tuzla and the Municipality of Lukavac (the western part of the City of Tuzla and the eastern part of the Municipality of Lukavac) is an area where degradation due to surface exploitation of coal and quartz sand has caused considerable disturbances. Also, in the immediate vicinity, in the western part of the City of Tuzla, there are slag and ash disposal sites of the „Tuzla“ Thermal Power plant, which seriously affect soil degradation and pollution of the environment, especially the watercourses.

Due to the aforementioned, two areas have been identified for priority intervention, i.e. areas where, based on defined guidelines and purposes, the Spatial Plan and adopted detailed documents would result in a phased recultivation and regulation of the land. These areas include the slag and ash disposal sites Divkovići I and II of the „Tuzla“ Thermal Power Plant, and the former strip mine „Šićki Brod“.

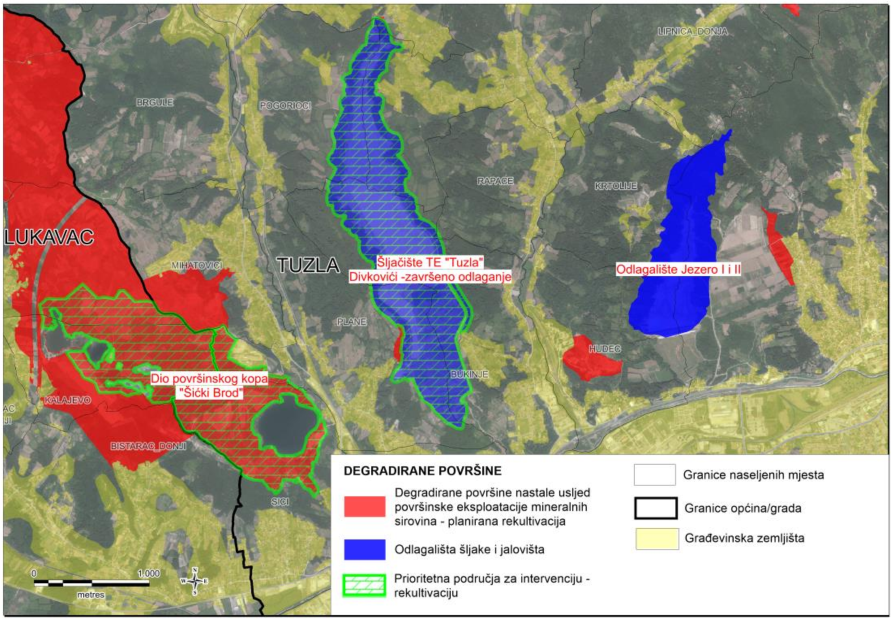


FIGURE 24. *Priority areas for intervention and recultivation*

Degraded areas

Degraded areas resulting from the surface exploitation of mineral resources–planned recultivation	Municipality/town boundaries
Disposal sites for slag and tailings	Boundaries of populated areas
Priority areas for intervention-recultivation	Building lands

Divkovići I and II, slag and ash disposal site of the „Tuzla“ Thermal Power Plant

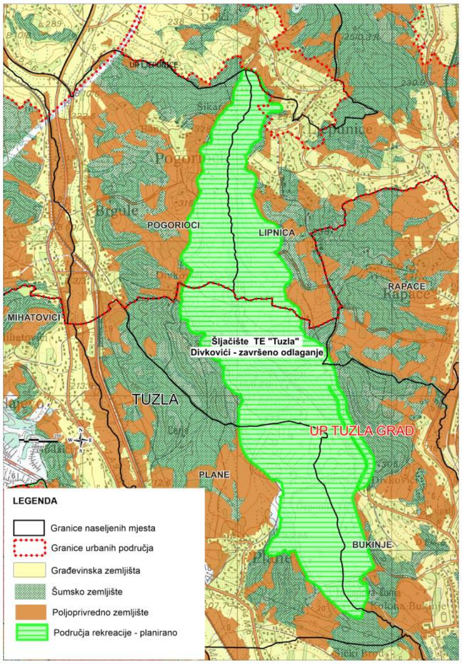


FIGURE 25. *Disposal site Divkovići I and II*

Boundaries of populated areas

Boundaries of urban areas

Building lands

Forest land

Agricultural land

Degraded areas–planned recultivation

The Divkovići I and II disposal site for slag and ash from the „Tuzla“ Thermal Power Plant is located in the western part of the city of Tuzla and covers an area of approximately 185 hectares. The thermal power plant ended with the disposal of combustion by-products – slag and ash in mid-2015, and only the zero-phase of recultivation has currently been done here involving backfilling and overlaying of 50 cm of soil material. The spatial plan is intended for the recultivation of all landfill areas upon their closure, based on previously prepared and adopted comprehensive planning documents.

Thus, a new use is planned for the Divkovići disposal site I and II, involving the regulation of the entire area and its equipment with appropriate amenities: sports and recreation grounds, playgrounds for children, green park areas, water surfaces incorporated into the environment, bicycle and pedestrian paths, etc. In this way, successful recultivation and reconstruction of heavily degraded land would significantly improve the quality of the environment of all inhabited places in the surrounding area, whose citizens have been threatened for years by the consequences of the disposal of slag and ash on this site.

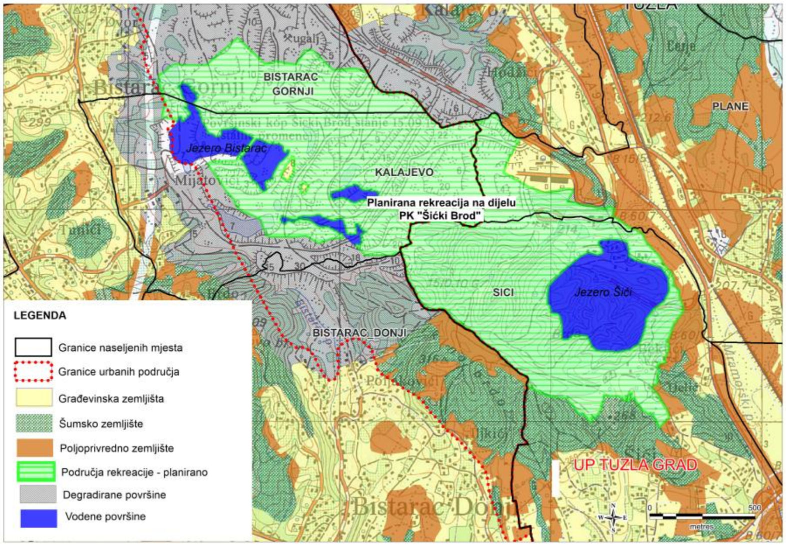


FIGURE 26. *Area of the closed surface mine „Šićki Brod"*

- Boundaries of populated areas
- Boundaries of urban areas
- Building lands
- Forest land
- Agricultural land
- Degraded areas–planned recultivation
- Degraded areas
- Water bodies

The area of the closed surface mine „Šićki Brod“ is located in the area of the City of Tuzla (western part) and the Municipality of Lukavac (eastern part). After the cessation of surface coal mining, several water reservoirs, among which „Šićki Brod“ and „Bistarac“ particularly stand out, were established on part of this area. In the previous period, in some parts of the subject area, land restoration occurred through succession, and landscaping of the area surrounding the water reservoirs also took place through individual initiatives. Taking into account all these facts and the needs of a large population gravitating to this area, The Tuzla Canton Spatial Plan defines recultivation and regulation of the entire area, i.e. allocates an area of 150 hectares for the recreation, and that area includes the aforementioned water reservoirs and the surrounding area. The zoning of particular land uses within the designated area will be defined by a detailed planning document (zoning plan or regulation plan), the mandatory preparation of which is prescribed by the Spatial Plan.

Since interventions in certain areas aimed at recultivation of damaged and degraded land are mostly interventions in space, i.e. projects whose implementation requires significant funding, they require the involvement of all actors in the process, from the local community to the cantons, the Federation and certainly the state, through international funds and donations.

Ultimately, the benefit to each municipality/town that has implemented rehabilitation and recultivation projects, as well as the benefit to the Tuzla Canton as a whole, is the land protection and regulation, regardless of the scale of the projects addressing this area. This approach, as seen, has not only local but also regional significance, and ultimately global. The essence of the UN Agenda 21 is to „think globally, and act locally“because only in this way the planet Earth could be preserved, or rather saved. The measures and activities planned within the Cantonal Ministry of Physical Planning and Environment and the Institute for Spatial Planning and Urban Planning is a good example and a roadmap for other areas in Bosnia and Herzegovina. However, it will take time for the whole society to raise awareness and sensitivity for regulating the land and creating better and more humane living conditions.

FIGURE 27. *Overburden disposal site Višća – Đurđevik in the Municipality of Živinice (Photo: H. Čustović)*

FIGURE 28. *Slag and ash disposal site Divkovići – Tuzla (Photo: H. Čustović)*

FIGURE 29. *Dust cloud above the landfill Divkovići I (Photo: B. Zarod)*

OVERVIEW OF BEST SUSTAINABLE LAND MANAGEMENT PRACTICES AND TECHNIQUES (TECHNIQUES, APPROACHES AND EXAMPLES FROM PRACTICE)

4

4.1. Agrotechnical And Biological Measures Of Sustainable Land Management

The success of agricultural production, especially intensive agriculture, depends entirely on the application of agro-technical and biological measures. Agrotechnical measures mostly relate to tillage, fertilization, conservation practices for retaining moisture and controlling erosion, while biological measures relate to the selection of appropriate species and varieties. On the other hand, organizing a good crop rotation is the best way to preserve soil biodiversity and plant health.

Sustainable land management in agriculture is unthinkable without measures of its regulation in terms of physical and chemical properties, crop rotation, and conservation measures from the standpoint of plant health, product quality, biodiversity, and soil energy and resilience to the increasingly frequent occurrence of droughts and floods.

Crop rotation

Crop rotation is the spatial and temporal rotation of crops. Along with tillage and fertilization, it is one of the oldest and most important agricultural practices. Appropriate crop rotation should not only maintain but also increase soil fertility in the long run. Crop rotation is also the cheapest measure with phytosanitary function, as it prevents the spread of diseases and the growth of the population of insects and plant disease pathogens, and reduces „soil fatigue“. The use of crop rotation increases biodiversity, reduces the risk of environmental pollution, reduces dependence on the chemical industry, and offer a higher possibility for recycling secondary raw materials from agriculture. It is recommended to alternate crops with different rooting depths, different consumption, and requirements for water and nutrients, different competitive abilities in relation to weeds, etc.

In today's plant production systems, land rest is practiced in many ways, including idle fallow, green fallow, cover crops, sideration, fallow, etc.

While choosing crops for crop rotation, and in view of protecting the soil from erosion and other forms of degradation, it is recommended to consider those that will cover the soil constantly. Thus, the main crop is usually combined with an intermediate crop, either summer or winter variety. Various combinations of crops are possible, for example: winter crop + summer crop (catch or subsequent); early spring crop + summer crop (catch or subsequent); late spring crop + winter intermediate crop; winter crop + winter intermediate crop.

Cover crops are those that are sown to completely cover the soil and thus prevent the growth and development of weeds, while protecting the soil from erosion. The consociation of coarse grasses, single or combined with perennial legumes, is the best example of cover crops in the function of weed control and soil protection from erosion, that is, a modern form of land rest with the long duration being its only drawback (Bokan, 2003).

The crop rotation cannot be readily taken from books or copied from the neighbor but must be tailored to the conditions of each farm. On the other hand, crop rotation effects are not visible in the short run. Positive effects on the yield levels are visible only after 2 - 3 crop rotations (6 - 10 years), while the dynamics of chemical and physical properties of the soil are stabilized only after 15 - 20 years.

The soil on slopes is exposed to water erosion, therefore, crops of dense assemblage should be grown and the period of soil being without crops should be as short as possible. According to the degree of erosion control, crops can be divided into four groups: i) crops that well protect soil from erosion: perennial grasses and perennial legumes; ii) crops that are less protective of soil from erosion: winter cereals and winter forage mixtures; iii) crops that accelerate soil erosion: spring cereals, spring forage mixtures, one-year legumes; iv) crops that dramatically accelerate soil erosion: raw crops.

Resting of land

Soil fatigue is a general term for all occurrences having an impact on the reduction of annual yield on a particular land plot, regardless of what conditions prevailed. Decreasing yields on exhausted land cannot be mitigated, nor reversed, by the application of larger amounts of mineral fertilizers or by more intensive protection.

Resting of land can be achieved by applying various measures such as lay-land, fallow, long-term fallow.

- The rest of the soil belongs to the migratory farming system, which implies that the soil is left to rest for ten years or more, and its fertility is restored under the impact of natural factors (wild grass); it can be used for grazing and mowing (mountain areas). After a while, the land is ploughed and turned into arable land again.
- Lay-land is practiced in permanent grassland areas, where one-year crops are grown at short intervals, and after 1 - 2 years the land is left to pasture vegetation, while a new area of grassland is being ploughed.
- Fallow belongs to the stationary farming systems. Fallow can be idle or black. If the parcel is not cultivated for one year, we are talking about idle fallow, and if it is cultivated than it is black fallow.
- Long-term fallow is idle fallow that has been left lying for several years. The term fallowed ploughland is often used, where the ploughland is left idle after harvesting, allowing grass and weeds to take over. Cattle were grazed on such ploughland. In this way, the cattle graze and fertilize the land at the same time.
- The fallow - black or green refers to sowing perennial grasses and legumes, whereby the soil is left to rest and accumulate organic matter thus enhancing the soil structure and quality forage is obtained along the way.

In all production systems, the involvement of perennial legumes in crop rotation fields is very important. This is one way to rest the land. On the other hand, after the exploitation of perennial legumes is over, the residues are ploughed in as green manure, and at the same time, a large amount of organic matter is accumulated in the soil, which remains available to the next crops. The cultivation of clover – grass mixtures connects crop and livestock production, enhances both of them, creating a harmonious soil-plant-domestic animal relationship.

Two harvests per year

From the aspect of sustainable land management and implementation of good practices, this system has several advantages, but also disadvantages. The cultivation of plants in the second sowing consumes carbon dioxide and produces oxygen.

The crops protect the soil from erosion, and the nutrients left behind from the previous crops are up-taken and therefore not lost due to leaching. Sowing catch crops also prevents aeolian erosion and aesthetically enhances the environment (Šarić *et al*., 1997). However, this production system has some serious drawbacks, primarily the removal of large quantities of nutrients from the soil, and twice the number of agrotechnical operations and machinery passage. Therefore, it is very important to adequately replenish the level of nutrients in the soil in order to prevent its depletion. This includes applying organic fertilizers, ploughing of crop residues, and growing legumes. Increased trampling and compacting of soil can only be prevented by reducing the number of operations, using double and wide wheels on tractors, leaving permanent tracks on the plot for machinery wheels, etc.

Consociation of crops

According to Jovanović *et al*. (2014), we often choose to combine different crops, i.e. consociation, which involves planting two or more plant species on the same field. The choice of species that will be next to each other should prevent negative allelopathy, while the competition for basic vegetation factors should be at the level present in monocropping. Species present in the consociation can use exactly the same vegetation space in different ways, the seeds can be mixed before sowing, or other species are sown into already formed rows, or each crop has its rows (separate sowing or replanting), or the sowing is performed in strips.

FIGURE 30. *Intercropping in research experiments (Photo: B. Ćupina)*

This type of growing plants has many advantages, as certain species are grown because they are designated as friends. Their role is manifold, and flowering, vegetable, medicinal, spice and melliferous species help by i) releasing odor (essential oils) or biochemical substances that repel insects; ii) attract pollinator insects; ii) attract verminous insects leaving the cultivated crop unaffected; iv) as green fertilizer they absorb nutrients and after subsequent ploughing they are returned into the soil; v) fixing soil nitrogen thus reducing the requirement for nitrogen fertilizers; vi) creating shade for lower-height plants that are sensitive to direct sunlight and climate change extremes; vii) protecting less resilient plants from wind and low temperatures; viii) providing natural support to climbing plants. Sometimes crops are grown only in such a way as to cover the soil as much as possible with their diversity and dense composition, to suffocate weeds and reduce soil erosion.

If certain plant species are intersown between wide rows of the main crop, the practice has shown that „living mulch" is established, which produces extremely good results in weed control, prevention of erosion, and infiltration of water into the arable soil. Experience has shown that cover crops can replace one or more cultivations for weed control. However, it is of much greater importance in preventing erosion and reducing tillage, especially as habitats for beneficial insects, thereby reducing the occurrence of diseases and pests.

Cover crops

Cover crops usually absorb nutrients and moisture that are not absorbed by the main crop, thus binding them and preventing their loss due to leaching into deeper layers of soil or evaporation. A good cover crop should have the following characteristics: i) plants germinate and sprout quickly, controlling erosion very shortly after sowing, quickly establishing soil resistance to trampling by agricultural machinery; iii) the measure may also be applied to less fertile soils; iv) relatively inexpensive for maintenance; v) improves the structure of the topsoil and facilitates faster infiltration of water, increases water retention capacity and moisture reserves; vi) with regard to the improvement of the physical soil properties, especially the structure, the energy, and fuel consumption during the next cycle of tillage and application of agrotechnical measures is reduced.

Mulching

The purpose of mulch is to prevent water loss from the soil, improve water and air regime and structure, boost soil biological activity, improve plant nutrition, and prevent weeds from sprouting.

„Dead" mulch can be different materials such as rock, gravel, sand, sawdust, hay, straw, manure, peat, paper, biodegradable materials, and various types of foil. Each of these materials has advantages and disadvantages.

Photodegradable plastic mulches (foils) decompose after some time, so there is no risk of soil contamination. The same happens with paper mulches made of straw and peat. After a while, they are ploughed into the soil, thus enriching it with organic matter. „Living" mulch is usually plants of lower height whose dense set covers the soil. These plants must not compete with the main crop, and after their role is done, they are ploughed as green fertilizer.

Permaculture

According to Kisić (2014), permaculture is a method of designing sustainable human communities simulating the patterns from intact nature and includes settings for organic agriculture, agro-forestry, sustainable development and applied ecology. Permaculture is designed to progressively reduce the consumption of energy and natural resources. It combines traditional knowledge with modern achievements and methods based on low-investment agriculture.

Water harvesting is a mandatory way of permaculture water management. Most often it is harvested during periods when the plants do not need it (winter), and then used for irrigation. It also works to mitigate erosion and landslides.

Permaculture is one way we can mitigate, but not prevent adverse climate change. Through permaculture, all organic waste generated on the farm is directed towards composting and reuse. The link between plant and animal production is one of the cornerstones of permaculture. In this way, it is possible to provide manure, and with compost and green fertilization it is possible to provide sufficient nutrients from one's own sources. Chickens and pigs dig and root around the ground. After they have loosened the soil and fertilized it at the same time, they are moved to another place. Moving the grazing cattle from one area to another has the same effect. Instead of agro-chemicals, it implies the use of as many natural „enemies“ and beneficial insects as possible. The introduction of deep-rooted crops (alfalfa) provides more benefits compared to the use of tools for loosening deep soil layers. Agroforestry is also part of permaculture.

Conditions and significance of the applied sustainable land management measures and practices

The aforementioned measures and practices, individually or in combination, should serve to improve land conditions and contribute to SLM. It should be borne in mind that improving land conditions, stopping degradation or rehabilitating degraded land, has direct positive effects on the state of agricultural production and living conditions of the population, as well as on the ecosystem soil functions from the aspect of its health (healthy land) and appearance (landscape).

Proper selection of the suitable intercrops or mixtures for specific agro-ecological conditions, requires a close analysis of the situation and it needs to be determined which of the primary benefits of the intercropping and this type of technology is to be achieved at all. From the standpoint of sustainable land management, technologies should improve some of the soil properties that are minimal, to maintain the existing fertility and productivity or to improve it.

It could be enrichment with organic matter (humus), enrichment with nitrogen, improvement of soil structure, water infiltration, erosion control, etc., but not necessarily in the function of plant production and profit.

Additionally, technology of each of these measures should be elaborated in detail for each specific agroecological situation and land plot to which the measure is applied. For example, for making appropriate consociation of crops care must be taken that the species tolerate each other; have different height; different requirements for heat, water and nutrients.

The choice of species and varieties in all plant production systems is a very significant measure. The species and varieties we choose may protect the soil from various forms of degradation, but can also work in the opposite direction. Jovanović *et al*. (2014) state that it is very important to choose indigenous (domestic) varieties in the organic production system, which ensures the safety in production from the aspect of their adaptation to local agro-ecological conditions, and because of the preservation of biodiversity. Agrotechnical measures cannot exclude the negative effects of drought, but their complex application can contribute to their mitigation. Of these measures, the most significant are crop rotation, pre-crops, sowing structure, tillage, fertilization, mulching, choice of varieties, sowing time and composition density, weed control and protective forest belts.

In the dry years, crop rotations with a higher proportion of cereals and other early pre-crops (Molnar and Milošev, 1994) have proved to be more favorable. Properly and timely performed tillage can considerably reduce the evaporation of water from the soil.

Regular application of organic matter to the soil can effectively mitigate the effects of drought. This measure has a positive effect on the balance of humus, on the activity of microorganisms, on the formation of stable structural aggregates, which is reflected in the range of physical properties of soil, in the first place its water, air and thermal regime. In arid conditions, the most important role of humus is associated with its capacity to absorb large amounts of water, thus increasing the holding strength and the content of easily accessible water. Balanced fertilization with an increased share of nitrogen in the ammonium form (UREA) also produces good results.

Mulching significantly reduces evaporation, fluctuations in soil temperature, impedes weed growth, and very effectively protects soil from erosion and deflation. The choice of species and varieties should be adjusted to the soil and climatic conditions. In light sandy soils with adverse water regime, winter species prevail, with rye and winter barley as main cereals.

Wheat, for example, due to the longer vegetation on these soils, in dry years significantly reduces the yield. Such habitats should not be used to grow spring row crops (maize, sugar beets, sunflower, soybeans, etc.), as even in wetter years, but with adverse rainfall distribution and short dry periods within the growing season, their yields can be drastically reduced.

When it comes to the choice of varieties and hybrids with a high frequency of dry years, in both cereals and row crops, genotypes with the shorter growing season, which on average can yield 30 - 40% more than medium late or late genotypes, are preferred. Sowing at the optimal agrotechnical term is one of the most inexpensive ways to increase yields. However, it should be noted that this can only be achieved under conditions of cultivated soil ready to receive the seed and enable its unimpeded process of germination, and initial growth and development. Even the best choice of species, varieties or hybrids, and best agrotechnical practices cannot produce optimum yields in poor physical conditions and exhausted soil.

The rule applicable to each habitat is that crops should be sown within their optimal timelines. Sowing should start with late and end with early genotypes. Sowing within optimal terms is particularly important in arid conditions as it enables better growth and development of crops and better utilization of pre-vegetation soil moisture reserves.

Microorganisms also have a positive effect on increasing the tolerance of agricultural crops to abiotic stresses.

They produce indole acetic acid, gibberellins and other substances that influence the increase in root hairs and overall root area, which has a positive effect on the plant's nutrient uptake.

Soils with a more favorable aggregate structure (finely crumbly) provide a higher presence of microorganisms, higher content of accessible water and accessible forms of nutrients to the plant than soils with larger aggregate structure, especially caused by hydromorphism, soil compaction, presence of a large quantity of clay fractions, etc.

4.2. Tillage Methods In The Function Of Applying Good Practices And Preventing Soil Degradation

Proper tillage is the most effective way to increase fertility, and fertility is the most important property of soil as a natural resource. Improper tillage leads to many degradation processes in the soil, such as damaged structure, erosion, reduced content of humus, disturbed water cycle, etc. Therefore, soil-tilling activities should be directed towards: i) the creation and maintenance of the humus layer, ii) preservation and increase of microbial activity in the soil.

In addition to the aforementioned negative effects, tillage is the biggest energy consumer. For this reason, all options are sought to avoid the negative effects of tillage and reduce energy costs. Different tillage technologies have been developed in the world, such as a minimum or reduced tillage system. Jug *et al*. (2015) explain these tillage systems as follows:

a) *Reducing the conventional tillage systems*, which implies that one or more operations, such as stubble dusting, summer deep ploughing, etc., involved in the tillage for spring or winter crops, are left out.

b) *Minimum tillage* implies that some of the conventional operations are completely left out, while some others are combined. Reducing tillage depth, using the extended effect of deep tillage for pre-crops, strip tillage, are some examples of this reduced tillage.

c) *No-tillage* or *zero tillage* is a minimum tillage practice in which the crop is sown directly into the soil without previous tilling. This system is only possible with the application of total herbicides that destroy all vegetation.

   For this reduced tillage system, it is very important to have an adequate seed drill that will sow the seeds by positioning them in the soil to a specific depth, given that it was not tilled.

d) *Conservation tillage* is a reduced tillage system in which the harvest residues are shallowly ploughed, or kept as close to the soil surface as possible, or by maintaining the soil surface that is not flat. At least 30% of harvesting residues should be left and ploughed.

One of the reasons why conventional ploughing with the overturning of the top layer of soil is avoided is the fact that it requires a large amount of energy and when replaced with direct sowing can save 30 to 40% time, labor and fuel for mechanization (FAO, 2014).

For our agropedological conditions, Mihalić and Bašić (1997) recommend conservation tillage only if the soil is of high fertility and in favorable climatic conditions, i.e. on soils that require no reclamation or fertilization. They also point out that *zero tillage* is a system that requires expensive equipment, it does not apply to dense assemblage, consumes a lot of herbicides for weed control, and applies a lot of nitrogen fertilizers and is therefore environmentally questionable.

Jug *et al*. (2015) also give their perception of these systems under our conditions, placing the focus on the fact that conventional tillage in today's climate change conditions must be complemented by and combined with various forms of reduced tillage. One of the main goals of deep tillage in the fall is the accumulation of rainfall during the fall and winter, which happens in favorable years. However, if we have a winter with little rainfall (which is increasingly happening), there will be no accumulation of moisture, but on the contrary, the ploughed soil will be exposed to even bigger drying. One solution is to shallowly plough harvesting residues, i.e. leave them as close to the soil surface as possible. The more harvest residues we have close to the soil surface, the bigger the moisture accumulation. In our country, these residues are often burned or left on the field so that lush weed vegetation develops through them by the end of the season. The choice of the form of reduced tillage that will be used is conditioned by a complex plant-soil-environment-human relationship. There is no universal system, and the best solution must be sought based on specific conditions.

Tillage in the function of erosion control

Erosion is one of the most significant factors of soil degradation in the world, as well as one of the largest water polluters. One of the major causes of erosion is a relief, so tillage must be adjusted to the slope.

Measures that can significantly contribute to the lowdown and reduction of erosion include contour tillage, in-field grass barriers, continuous crop rotation, enriching soil with humus, avoiding trampling by machinery, and practicing various consociations of crops.

One of the ways to reduce erosion is through conservation tillage leaving plant residues close to the soil surface thus reducing the devastating effect of raindrops. Mulching, whether dead or living, is also very important.

Tillage leads to faster loss of organic matter from the soil. The biggest loss occurs after clear-cutting and ploughing of natural grasslands.

The application of these types of reduced tillage and mulching are used to reduce organic matter loss (Jug *et al.*, 2015).

TABLE 12. *Anti-erosion effect of various crops during the year (Kisić, 2016)*

Crop	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Critical erosion periods												
Grasslands and regulated pastures												
Grazing pastures												
CGM (accompanying crop)												
CGM (one-year crops)												
Clovers (accompanying crop)												
Clover (first year of use)												
Clover (second year of use)												
Alfalfa (sowing year)												
Alfalfa (utilization year)												
Winter barley												
Winter wheat (early sowing term)												
Winter wheat (late sowing term)												
Rapeseed												
Oats (optimal sowing time)												
Spring wheat (optimal sowing time)												
Soybean												
Maize												
Potato												
Sugar beet												
Sunflower												
Second crop												

Color Legend	
Soil protection ranging from 75 to 100%	Soil protection ranging from 0 to 25%
Soil protection ranging from 50 to 75%	Soil without crops
Soil protection ranging from 25 to 50%	Critical erosion periods

Kisić (2016) states, considering all the advantages and disadvantages of tillage method, that from the production of erosion deposits to the yields achieved, all tillage and sowing methods perpendicular to the slope have proven to be most effective in stopping the surface runoff. They have also proven to be the most economical, cost-effective, soil protecting, and environmentally friendly, and the achieved yields are satisfactory.

Mihalić and Bašić (1997) provide a more detailed explanation of the ridge and furrow ploughing method. This ploughing method can be practiced by double plows with two boards and a joint ploughshare. Efforts should be made to keep the ridges oriented north-south. Water is accumulated in furrows, while the sides are sunlit and dry. This farming method is quite extensive and labor-consuming. Due to the accumulation of water in the furrows, there is no rapid runoff down the slope, which prevents soil erosion.

Fertilization with organic and mineral fertilizers

Fertilization with mineral and organic fertilizers can be called integrated fertilization, which is becoming increasingly accepted and supported around the world. Although fertilizing with organic fertilizers is complex and demanding, it is considered a very important factor in sustainable land management, as well as a buffer that halts or mitigates adverse processes of land degradation caused by human activities and tillage.

Considering that a lot is known about mineral and organic fertilizers in agronomic practice, as well as about technologies of organic fertilization, preparation and application of animal manure, green fertilizers and the role of legumes, composting of plant residues, ploughing of plant residues, etc., which is the subject of production technology, agrochemistry and plant nutrition, as well as about their positive effects, our intention is to draw attention to the fact that negative occurrences and effects can be expected as well.

Lončarić and Haman (2015) state that from the aspect of fertilization, the largest ecological burden is excessive fertilization with nitrogen and/or phosphorus, but inadequate fertilization, application of inappropriate forms of nutrients (e.g. application of nitrate nitrogen in the fall), or the application of fertilizers in an inappropriate way (e.g. application of slurry on saturated soil or spreading manure on the surface without introduction into the soil) can be equally burdening. A significant anthropogenic change in the agrosphere is the intensification of nutrient cycling that is achieved by the application of mineral, organic and green fertilizers.

All fertilization tasks can be reduced down to one objective, and that is the optimum availability of nutrients. This is not easy to achieve, as it is not a universal number, but different ranges determined for each nutrient and adjusted to the species and varieties, soil fertility, agroecological conditions and production objectives.

Fertilization mistakes can be reduced to several important issues relating to i) the state and knowledge of the actual fertility of the soil in terms of its physical, chemical and biological properties; ii) knowledge of the bio-physiological requirements of the cultivated plants in connection with the dynamic processes of soil nutrients and moisture; iii) lack of knowledge in the interpretation of analyzes and technologies in general in the production process; iv) lack of knowledge about soil nutrient balance in terms of output through yield and input through fertilization; v) poor quality of fertilizers applied and inadequate way and time of application.

Today, soil conditioners (soil improvers) are commonly used. These substances are added to the soil in order to improve its physical and chemical properties, as well as the biological activity of the soil. The most widespread method is calcification, which reduces soil acidity. The conditioners impacting on the physical properties of the soil include: pearlite, vermiculite, water soil crystals, mulches, horticultural sand and peat; and conditioners impacting on the physicochemical properties are composts and zeolites. Zeolites are natural materials of high exchange capacity. They easily lose and receive water as well as other substances. They can absorb water up to 55% of their weight, and gradually release it into the root zone of plants (Lončarić and Haman, 2015).

Green fertilization (sideration)

Green fertilization is the ploughing of green plant mass, grown for this purpose, in the soil. Crops used for this purpose are the ones that grow quickly and yield large amounts of organic matter. They can be used as monocrops or in consociations. They can also be grown as pre-crops, intercrops and subsequent crops, and rarely throughout the year.

Depending on the conditions, after 4 – 10 weeks of growing, or prior to sowing at the latest, the plants are mowed and ploughed, or left as mulch. Green fertilization enriches the soil with nitrogen from the green mass, and legumes thanks to their root-nodule bacteria enrich the soil with nitrogen from the atmosphere. The purpose of growing these crops in not to produce yields, but to bring into the soil the green mass whose decomposition will provide the next crop with better conditions for development.

For green fertilization, it is better to combine two types of siderate: legumes and non-legumes. Rape, mustard, colza, and rapeseed are recommended as the non-leguminous, and lupins, vetches, broad beans, birdsfoot, and serradella of leguminous plants.

Kisić (2014) states that in addition to green fertilization, two new terms, rhizodeposition and bio-tillage, have appeared recently.

Rhizodeposition is explained by the fact that green fertilization crops, having deep roots, bring nutrients from deep into the shallow layers thus returning them into the biological cycle. Bio - tillage implies that the crops, by their roots, loosen the compact sub-arable layer thus enabling bio-tillage as well as circulation of water and nutrients, both in ascending and descending direction.

Green fertilization crops should be carefully chosen, brought into the soil in a timely manner and properly managed, which ultimately leads to an increase in the content of soil organic matter, and the improvement of the soil structure and water regime, but only after many years of application. This method of fertilization is considered good agricultural practice, especially in vulnerable areas exposed to erosion.

In production systems (organic, conventional) in which soil fertility is maintained by resources available on the farm, energy consumption, greenhouse gas emissions, and the possibility of soil degradation are considerably lower. The use of manure, compost, green fertilizers, cultivation of legumes, crop rotation with several components, are measures that can achieve significantly more favorable ecological effects even in modern agriculture, and thus protect the soil as a basis for agricultural production in the first place.

Combined animal husbandry and crop production is the best way of closing the cycle of matter, in which the animal and plant production system can achieve the balance between input and output of mass.

4.3. Soil Contamination

Environmental contamination by heavy metals and organic pollutants is a global phenomenon today. Unlike other types of pollution, such as air pollution or ozone depletion, soil contamination is directly dependent on how it is exposed to local sources of pollution. When pollutants are present in soil in higher concentrations, there is a risk of entering the food chain and causing health problems in humans and animals.

Contamination implies a process of various pollutants in all aggregate states, meaning gaseous, liquid, or solid, entering the soil. The effects of contamination can also be expected on the living realm of the soil (edaphons). The changes are first reflected on the microorganisms and then on pedofauna. After that, changes may also manifest themselves in the deterioration of chemical and physical properties of the soil, when their concentrations exceed the permitted thresholds and standards.

Soil is a very complex mechanism. Due to its huge sorptive capacity, it represents a universal purifier – a decontaminator, as it retains pollutants on the surface of its colloids, preventing them from leaching into deeper layers of soil and groundwater. It is important to know that up to a certain extent, pollutants on a colloidal particle can bind into insoluble form and thus be neutralized as harmful substances. On the other hand, the soil contains a large number of useful microorganisms that decompose organic matter, and residues are deposited in an insoluble form that is not harmful to crops and the soil ecosystem. In addition, the soil has a greater or lesser buffering capacity, i.e. the ability to resist the change of reaction – acidification or alkalization.

However, all these soil properties have their limited capacity, which means that they are only able to counteract negative effects to a certain extent. The divergence of soil types, varieties, and forms in nature is extremely high. Even in the same profile, at its vertical cross-section, individual horizons may show significant differences relating to this property of the soil. Anisotropy and diversity in the horizontal and vertical direction, when it comes to the soil in Bosnia and Herzegovina, is very much present as a result of geomorphology, relief and other pedogenetic factors influencing the formation of soil.

The term *heavy metals* refers to all high-density chemical elements (metals) *(heavy metals are elements with a specific density greater than 5 g/cm^3)* that are toxic at low concentrations. They are a natural component of the earth's crust. Through food, water and air, a man brings very small amounts of these elements into their body. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are necessary for the metabolism of the human body. However, higher concentrations can lead to poisoning and serious health problems (especially Pb, Zn, Cd, Cu, Ni, Cr, Co, and Mn).

The term *total petroleum hydrocarbons* (TPH) is a term used to describe a large family of several hundred chemical compounds that originally come from petroleum and petroleum products. Because there are so many different chemicals in crude oil and in other petroleum products, it is not practical to measure each one separately. However, it is useful to measure the total amount of TPH in the soil.

A separate group of petroleum carbohydrates consists of *polycyclic aromatic hydrocarbons* (PAH). These are organic compounds consisting of two or more fused benzene rings. Natural sources of PAHs are wildfires and volcanic eruptions. They are an integral part of most fossil fuels and cue to incomplete decomposition; they participate in environmental pollution. The harmfulness of these elements is reflected in their carcinogenic effect (especially benzo(A)anthracene, benzo(A)pyrene, benzo(B)fluoranthene, benzo(K)fluoranthene, chrysene, dibenzoanthracene, indenopyrene, etc.

Causes and effects of soil contamination

Contaminated soil threatens the quality of crops that are constantly exposed to other adverse effects as well, with the accumulation of certain toxic substances in plants or their various organs, edible or inedible parts.

The consequence of this accumulation of toxicants in plants has a negative impact on the health of humans and animals consuming such agricultural products. Heavy metals and organic pollutants originating in industrial plants are a particular hazard.

For these reasons, continuous monitoring of the physical and chemical properties of soil and plants is necessary, in order to monitor changes and determine the prevention of degradation, and potentially develop soil remediation programs.

The goal of protecting the soil is to prevent its contamination, while on the other hand, the remediation of the contaminated soil related to cleaning, remedying and reusing the soil. Thus, the effects on agricultural crops may be such that when soil pollutant concentrations exceed certain permitted limits, these plants should not be used in human or animal nutrition. On the other hand, some contaminants have a very adverse effect on the soil living world (edaphon), such as microorganisms and pedofauna, and can lead to the disappearance of very useful microorganisms, i.e. to soil sterilization. Destruction of the living world causes deterioration of the water-physical properties of the soil, such as deterioration of the structure, deterioration of water permeability, compaction, etc. The ultimate consequence is the poor quality of food and reduced yields of agricultural crops.

The amount of heavy metals in the soil depends on many factors and processes occurring therein, but primarily on the character and properties of the geological substrate on which the soil was formed. Certain soil factors such as pH, soil colloids adsorption capacity, oxidation-reduction potential and chemical reactions of organic and inorganic origin, have a direct impact on the accessibility of most heavy metals and microelements in the soil.

If microelements in the soil are present in amounts that are within the range of the natural properties of the soil, they can play a very important role in plant nutrition as they support various bio-physiological processes. However, microelements in amounts exceeding the permitted limit can be very harmful, and at that point, we call them heavy metals. Besides, the total content of microelements and heavy metals does not necessarily mean that they are accessible to plants. In acidic pH reaction, the mobility of almost all heavy metals and microelements, especially manganese, zinc, cobalt, copper, cadmium, etc., is increased.

Not all heavy metals have the same ability to accumulate in certain plants. For example, cadmium, zinc, molybdenum, and cobalt have a high capacity to absorb and accumulate in certain organs of cultivated plants, while manganese and iron have a lower capacity. Plants least accumulate in their organs copper, lead and chromium. On the other hand, the mobility of heavy metals in soil solution, under the same pH reaction and other factors, is not the same. Manganese, cadmium, molybdenum, and selenium have the highest mobility, and therefore the rate of uptake by plants, then come nickel, cobalt and copper with the medium, while chromium, lead and mercury have poor mobility.

In addition to the soil reaction, various antagonisms occur between the ions of heavy metals and microelements. For example, free calcium ions reduce the accessibility of boron to the plants, which results in a decrease in the resilience of certain crops to diseases (sugar beet root rot, brown spot in cruciferous vegetables, rapeseed brown core, and chlorosis in alfalfa). Significant amounts of copper are inactivated when large quantities of organic matter (humus) are brought into the soil. There are many such antagonisms when it comes to trace elements and heavy metals in soil. Large amounts of heavy metals can be toxic to the plant, causing disturbances in enzymatic processes and biochemical reactions. The inhibition of biologically important enzymes is an important molecular mechanism caused by metallic toxicity. The presence of some of them has the opposite effect on the presence of some other elements. Excessive content of copper or copper sulfate, which is a frequent occurrence in viticulture, adversely impacts on the uptake of molybdenum; iron deficiency is higher if there is an increased presence of zinc, manganese, copper and molybdenum.

Increased phosphorus content in soil can lead to zinc, iron, or copper deficiency, as well as to increased adsorption of molybdenum. Uncontrolled nitrogen fertilization leads to reduced accessibility of copper and zinc, or, if the soil contains an increased amount of sodium and potassium, the uptake of manganese by plants is reduced. Likewise, the excess presence of iron, copper or zinc, reduces the adsorption of manganese to the adsorptive complex of the colloidal particle.

The antagonism of these reactions can be used to reduce the toxicity (contamination) of some of the heavy metals in the soil. As can be seen, heavy metals as well as trace elements and their dynamics in soil solution, participate in the very complex nature of the biological transformation of matter, with the balance being very important from the standpoint of agricultural product quality and sustainable land management in the function of environmental protection.

Heavy metal emissions from metallurgical plants and thermal power plants affect their anthropogenic distribution in soil and ecosystems in their immediate vicinity. Therefore, the production of many agricultural crops on such soils is risky for the potential inclusion of heavy metals into the human and animal food chains (Goletić, 2011).

Because of the adaptability of toxic metals, it happens that they get a clear way into the plant's cell, whereby they can disrupt the essential metals that mediate cellular functions. For example, the mechanism of toxicity of cadmium, copper and nickel affects the replacement of zinc, which is commonly known as mimicry.

Likewise, the element thallium can mimic potassium, and manganese iron, being the key factor of its toxicity. This phenomenon of imitation allows arsenates and vandanates as toxic metals, instead of phosphates, to provide cellular transport and their accumulation in plant organs. Thallium mimicking potassium and manganese iron is the key factor of their toxicity. Selenates, molybdates and chromates can mimic sulfate molecules.

The presence of heavy metals has other adverse characteristics as well. The chemical reactions of heavy metals lead to oxidative damage.

Most heavy metals can act as a catalytic center for redox reactions with molecular oxygen or other endogenous oxidants. These reactions create oxidative modifications of biomolecules such as proteins or DNA.

Another key chemical reaction, which is conditioned by metallic action, is oxidative damage. Free radicals are generated in these reactions, with some metals becoming carcinogenic. These radicals are generated not only at the expense of oxygen but also in the presence of sulfur, carbon, etc. Oxidative damage, by the production of free radicals, can be a key factor in the carcinogenicity of some metals. In addition to oxygen-based radicals, some sulfur and carbon-based radicals may occur as well.

The protection of human health is always at the forefront. In order to achieve preventive protection of human and animal health, the processes and procedures in food production need to be monitored and the concentration of heavy metals needs to be measured in an integrated way – from field to table.

Today, many countries seek to limit the content of heavy metals and other harmful substances in the human and animal food chains, as well as their impact on the entire ecosystem, through legislation. European Union's legislation prescribing the maximum permissible concentrations of certain metals is very important to us. An example of this is EC/1881/2006 regulation governing maximum permissible concentrations of lead, cadmium, mercury and tin in food.

Radioactive elements may also occur in the soil. Soils formed on the eruptive rocks or those originating from these rocks have a higher degree of radioactivity compared to those formed on sedimentary or metamorphic rocks. Radioactive elements in the soil are formed mainly by the decomposition of uranium and thorium. It is not known exactly how they work, but it is believed that they can significantly direct chemical and biochemical processes in soil. Anthropogenic radioactivity in the soil can be expected as a result of war activities, medical waste, and some industrial waste materials that are inadequately disposed of.

In addition to heavy metals, soil contamination is also largely affected by *organic pollutants.* PAHs stand out from the many organic pollutants, which are becoming increasingly present in Bosnia and Herzegovina and are therefore the most tested.

Due to their long period of environmental degradation and toxicity, polycyclic aromatic hydrocarbons belong to the group of persistent organic pollutants (*Persistent Organic Pollutants* - POPs). Their degradation products (oxygen and nitrogen derivatives) are also an environmental hazard. Therefore, PAHs and their degradation products are toxic organic compounds. They exhibit carcinogenic effects, leading to acute toxicity, developmental and reproductive toxicity, cytotoxicity and genotoxicity so that toxic PAHs can be found in food and the environment.

Like heavy metals, PAHs can also be of natural or anthropogenic origin. PAHs consist of two or more fused benzene rings and are the result of incomplete combustion of coal, oil, petroleum gas, organic waste and various organic substances. In addition, huge amounts of PAHs come from the processing and production oil, coke, tar, asphalt and soot, which is very common in central Bosnia and Herzegovina. Over time, PAHs accumulate in water, air and soil, and subsequently can easily get into the human food chain. On the other hand, a certain amount of PAHs can be found in food due to inadequate preparation, or as a result of the decomposition of organic components of food, which requires special attention.

There are more than 100 different PAHs that most commonly occur in mixtures, but in some cases, they are found as single compounds. PAHs are widely spread in all parts of the biosphere. They can be found in industrial and municipal wastewater, from where they rapidly distribute through the hydrosphere and are transformed. Also, due to the incomplete combustion of organic matters and the formation of fine aerosol, they can be found in the atmosphere.

The largest accumulation of PAHs is recorded in the soil, because of oil spills, wildfires, volcanic activities, presence of industrial and municipal waste in the soil, and atmospheric deposition. Although there are a large number of different PAHs, only 16 are defined by the European Union as a priority (European Commission, 2005).

In addition to PAH compounds, our legislation also addresses PCBs or polychlorinated biphenyls, as well as chlorinated hydrocarbon-based insecticides and other plant protection chemicals such as anthrazine and simazine, which can also be found in soil. Polychlorinated biphenyls or PCBs are a mixture of synthetic organic compounds with the same basic chemical structure as other chlorinated cyclic carbohydrates. They were first produced on an industrial scale in 1929, in the chemical industry. PCBs can enter the body through the skin or by ingestion, and are then deposited in fatty tissues without any possibility of degradation. Legislation defines hazardous substances, which include waste materials containing or contaminated with polychlorinated biphenyls. These hazardous substances are subject to special characterization requirements that are also defined by international regulations (Basel Convention).

In the environment, PCBs can be found in industrial landfills. Through water leaching, they get into the soil and groundwater. In the environment, PCBs are spread by air, water, soil, and living organisms. Of the total amount of PCBs present in nature, 99% is in water, 0.3% in air, and the remaining percentage is evenly distributed to the soil, sediments, etc.

An example of soil properties and area risk profilefor the presence of heavy metals

Considering that soil reaction is one of the most important, if not the most important factor of mobility, and thus the accessibility of pollutants to plants, animals, and even man, the following paragraphs (Table 13.) list the surface of risk areas from the standpoint of contamination in terms of pH reaction, and Figure 31. shows their spatial distribution in the Federation of Bosnia and Herzegovina.

Areas with a *potentially high risk* of contamination with pollutants consist of soils that are extremely acidic with a pH below 4.5, with light texture, non-carbonate and with a relatively small share of humus in the soil profile. These are mainly distric brown soils, rankers, luvisols, acrisols, podzols, deposols, etc. Such soils account for about 10% or 9.69% (252,129.74 ha) to be precise. The aforementioned types of soil are most represented in the Una - Sana, Tuzla and Central - Bosnia Cantons, and least in the area of Herzegovina.

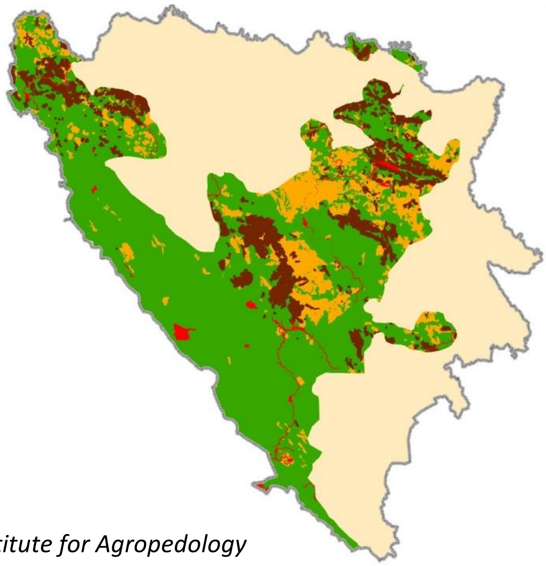
Another area with *potentially medium risk* of contamination with pollutants consists of soils whose pH ranges from 4.5 to 5.5. These soils are of relatively lighter, loamy structure, medium humic, non-carbonate and medium deep. Here too we have distric brown, colluvial, pseudogley soils and rankers, formed on different geological substrates or substrate mixtures, with a slightly higher pH or less affected by leaching and the process of unbasification. They are represented on 13.1% of the territory of the Federation of Bosnia and Herzegovina, or 338,753.18 hectares, mostly in the Sarajevo, Central Bosnia, Zenica - Doboj and some in Tuzla cantons.

The third largest area consists of soil group whose pH is above 5.5. These are heavier loamy-clayey soils, carbonate, quite humic. Eutric brown soils, calcocambisols, calcomelanosols, rendzinas, smonitza, alluvial soils, humofluvisols, peat, etc., are represented in this group of soils. This are covers a total of 1,985,736.72 hectares or 76.28% of the territory.

Given the physical and chemical properties of the soils represented, they have the *least risk* of contamination with pollutants, or rather, in these soils, the contaminants are the least mobile and accessible to plants, and are more slowly leached into watercourses. This is the area of entire Herzegovina, and parts of the Una - Sana, Central Bosnia, Zenica - Doboj and Tuzla cantons. In the Dinaric karst area, regardless of the favorable pH, the relative shallowness and skeletness of the soil may increase the risk.

TABLE 13. *The levels of risk of soil contamination with pollutants with respect to soil pH in the Federation of Bosnia and Herzegovina*[27]

Level of risk		Area (ha)	%
High risk areas	pH< 4,5	252,129.74	9.69
Medium risk areas	pH 4,5 – 5,5	338,753.18	13.01
Low or no-risk areas	pH > 5,5	1,985,736.72	76.28
Urban areas, hydrography, mines,...		26,617.58	1.02
	Total	**2,603,237.22**	**100**



Source: Federal Institute for Agropedology

FIGURE 31. *Contamination risk map of the Federation of Bosnia and Herzegovina*

Color Legend	
	Areas with high risk of contamination with pollutants
	Areas with medium risk of contamination with pollutants
	Areas with low or no risk of contamination with pollutants
	Urban areas, hydrography, mines,...
	Republika Srpska

[27] Federal Institute for Agropedology

The sources of contamination of agricultural land can be different: application of pesticides and fertilizers, mining, loading and unloading of coal and fuels, disposal of coal ash, drainage of contaminated soil into surface water and again into the soil, outdoor urination and defecation, etc.

The fact is that soil can be contaminated by depositing contaminants from different sources, but it is certainly much better, easier and cheaper to prevent contamination than to decontaminate contaminated soil, i.e. to remediate it. However, if contamination does occur, remediation measures to apply can be physical (mechanical), chemical, and biological.

Physical decontamination measures are limited to the physical removal of the contaminated layer of soil by excavation and removal, while chemical and biological ones are carried out *in situ.*

Chemical measures are generally carried out by adding certain substances (detergents, some acids and solvents) that increase the solubility of pollutants, and thus their leaching from the soil. When implementing these measures, consideration should be given to possible groundwater contamination.

Another decontamination measure is electro-reclamation, i.e. the placing of electrodes with electricity into the soil, whereby heavy metals are „pumped out" from the soil by electro-osmosis and electrophoresis.

The next group of remediation measures is biological, which is actually the biological degradation of pollutants (especially organic ones) by microorganisms. Soil microorganisms are sown (entered) into contaminated soil and their enzymes decompose contaminants.

However, one of the cheapest soil decontamination measures is phytoremediation. The plants, through their roots, extract heavy metals and organic pollutants, thereby decontaminating the soil. Today, over 400 plant communities of hyperaccumulators are known worldwide, such as *Asteraceae, Brassicaceae, Caryophyllaceae, Cyperaceae, Cunouniaceae, Fabaceae, Flacourtiaceae, Lamiaceae, Poaceae, Violaceae and Euphobiaceae. Brassicaceae* with 11 genotypes and 87 varieties. Phytoremediation is potentially applicable to a large number of pollutants and is therefore considered a very effective and most commonly used measure in soil decontamination.

Utilization and recycling of nutrients from agricultural waste and municipal waste

Waste management is one of the most significant problems of the modern world. Agriculture, especially livestock farming, is a source of considerable amounts of waste. The principles of good agricultural practice[28] indicate what measures should be taken to protect soil, water and air while making the best use of the resulting waste. Accordingly, attention should be paid to the following recommendations:

- Choose the type of agricultural production depending on the soil and climate conditions,
- Avoid soil degradation, and carry out reclamation of previously degraded soil,
- Maintain or improve soil fertility by choosing appropriate tillage and crop cultivation methods,
- Conduct soil analysis at least once in every five years,
- A high yield can be achieved through the use of organic fertilizers,
- Application rates should be based on plant requirements and nutrient contents of the manure; the total amount of nitrogen applied to the soil must not exceed 170 kg/ha,
- Use the best fertilization technique and thus obtain maximum efficiency with a minimal negative impact on the crop and the environment,
- The number of animals and the available agricultural land to which the manure is applied should be in balance,
- Manure should be removed frequently from stables,
- Animals, stables, and manure storage facilities should be located in such a way that their negative impact on the environment is minimal,
- Water-damaging effluents (slurry, silage fluids, etc.) must not escape from livestock facilities, farm manure storage facilities, stored nutrients or other farm facilities,

[28] http://www.savjetodavna.hr/adminmax/File/vijesti/kodovi%20za%20tisak_web.pdf

- Data on the quantity, quality, type and period of application of fertilizer and pesticides must be kept for each land plot and kept for several years,
- The volume of manure storage at the time application is not allowed should be enough for six months, but tanks for a period of eight-month storage are recommended,
- Silage effluents resulting from the preparation and storage of silage should be collected in the storage facility,
- The livestock must be kept in conditions that support animal's life, health, and well-being, and therefore must have access to safe and good quality food and drinking water.

The storage, transport and application of manure and slurry are the most significant steps to prevent loss and pollution of the environment. Manure should be stored in watertight pools (e.g. concrete) which must be large enough to receive all manure collected over six months.

BiH farmers, just like European ones, will have to start implementing the Nitrate Directive. In the first period of implementation of the Nitrate Directive (usually four years), the annual amount of nitrogen farmers are allowed to add to the fertilizers of animal origin must not exceed 210 kg/ha, and after that period 170 kg/ha. The Nitrate Directive also limits the use of nitrogenous mineral fertilizers. They may only be used in the amounts representing a difference between the requirement of the crop for nitrogen in order to achieve a certain level of yield on the one hand, and the nitrogen that will become available to it through fertilizers of animal origin and mineralization of soil organic matter, on the other.

Organic fertilizers applied to the soil without vegetation cover should be incorporated into the soil as quickly as possible, by ploughing or cultivation. Organic fertilizers should be applied to agricultural land during the part of the year when the nutrients contained therein can be used by the crops grown. This is particularly important for liquid manure – slurry with a high content of ammonia-nitrogen (50 - 70%) that converts to nitrate in a few weeks and can, therefore, be lost through leaching.

Application before sowing winter crops is common but should be avoided because the climatic conditions and soil conditions in the fall are such that they can potentiate huge losses by leaching, especially in permeable soils. No solid manure should be applied to wet or water-saturated soil, or frozen or covered with snow.

Agriculture as a diffuse source of water pollution – eutrophication

The impact of food production on water pollution is very high. Agriculture is the largest consumer of fresh water, but also its major polluter. The type and degree of pollution depends on the nature of the pollution, the ecological conditions, the soil condition and the applied agricultural practice. In different parts of the world, soil and water degradation can take on a very large scale (global problem) or have a regional or local character. One of the most significant sources of diffuse water pollution is certainly agriculture, i.e. farm. It is estimated that Bosnia and Herzegovina has about five hundred thousand farms, of smaller or larger capacity. All of them individually, given the still underdeveloped system of farm management, represent a potential source of environmental pollution (Figure 32.).

FIGURE 32. *Improper disposal of farm manure (Photo: M. Đikić)*

This problem belongs to the group of complex environmental issues whose impacts are very broad. The magnitude of diffuse pollution depends on: i) natural occurrences in the catchment area, ii) soil types and chemistry, iii) type, composition, and size of vegetation cover, iv) density of the hydrographic network, v) types and quantities of substances applied to the soil surface, vi) the duration of the dry period preceding the precipitation, vii) the scope and intensity of the precipitation.

A major problem in arid areas is soil salinization, i.e. an increase in soil salt accumulation due to irrigation. By surface runoff and leaching, water used to irrigate carries dissolved salts and other biochemical residues thus contaminating surface water, underground aquifers, and reservoirs. Nitrates are major pollutants of groundwater, while the liquid waste of animal origin and waste from the food processing industry contaminate surface and groundwater. This is why some areas with intensive agriculture are major environmental polluters.

The soil properties and the vegetation largely regulate the water regime, the general state of the hydrological cycle, and the quality of water. In addition to floods in the lower regions and river valleys, water transports solid soil particles, along with nutrients useful for the plants, various pesticides, liquid waste from livestock and industrial production, etc., with all these substances in increased concentrations at the deposition site can be toxic.

Surface running water can purify itself, if the source of pollution is removed and pollutants prevented from getting into the surface water. However, groundwater is not easy to clean naturally.

Groundwater typically moves slowly, pollution is therefore slow, and contact with oxygen is very limited.

Natural treatment of polluted groundwater can take hundreds or thousands of years. This is one of humanity's biggest problems, in addition to the fact that the groundwater table is constantly lowering, due to imbalances in water revenues (precipitation) and expenditures (consumption). Expenditure is much higher than revenue, and it is agriculture that consumes the largest amounts of groundwater.

The surface waters enriched with nitrogen (N), phosphorus (P), and carbon (C) contribute to increasing the concentration of these elements in rivers and lakes. The increased levels of N and P result in a process of eutrophication. Eutrophication is the process of enriching water with nutrients, which results in the growth and development of aquatic plants. It may adversely affect the suitability of the use of water resources for other purposes. Increased production of aquatic plants leads to an increased content of organic matter, whose microbial decomposition produces unpleasant odors, consumes available oxygen, and impacts on the development of other aquatic organisms.

The degree of oxygen consumption, especially in cold and deep water, where decomposed organic matter can accumulate, may reduce the quality of fish habitats and encourage the reproduction of some other fish that are adapted to less oxygen and warmer surface water conditions. Anaerobic conditions can also cause the release of additional nutrients from the lowest sediment area. The nutrient-enriched water boosts the production of algae, thus increasing the turbidity and coloration of water. Excessive plant growth can interfere with certain recreational activities such as swimming and rowing.

Therefore, agriculture can be a significant polluter of nature, especially soil and water in the case of uncontrolled fertilization, irrigation, uncontrolled surface runoff of wastewater and other agricultural waters, as well as erosion. Rational land use measures and erosion control are the best protection against environmental damage and pollution. Nutrients (nitrates and phosphates) are discussed here as a type of diffuse pollution of water resources.

Land (plot) background and fertilization plan in the function of eutrophication control and environmental protection

The field (land plot) background is a document that contains all relevant information on the soil condition and improvement of the soil condition, applied agricultural practices, application of fertilizers, pesticides, achieved yields, and other different observations.

The background of a field or land plot shows specific conditions for the growth of the plants on each plot on the farm and the accumulated experience for the future elimination of possible mistakes. This is also useful for transferring experiences and knowledge to future generations.

Fertilization planning should be based on the latest available soil fertility data. For this reason, periodic soil fertility surveys are required, preferably every three to five years. Nitrogen content analysis is always carried out when it comes to intensive production, prior to the application of nitrogen fertilizers. The balance of plant nutrients is calculated every year. The principle of fertilization planning is based primarily on determining the total amount of plant nutrients according to the plant's requirements. The next step is to determine what amount and type of manure will cover the planned nutrient standard, and finally, determine the type and amount of mineral fertilizer to meet the remaining requirement for nutrients.

Diffuse nutrient losses in agriculture are strongly influenced by climate, soil type, crop cultivation method and form and amount of mineral fertilizers and manure that are applied. Diffuse phosphorus loss is caused by a factor such as soil susceptibility to erosion. The way of implementation of practices should always be elaborated, utilized and tailored to local or regional conditions.

Technological and scientific development will also play an important role in the effort to improve nutrient utilization efficiency in agriculture. Certain technologies already exist that make fertilizer use efficient and profitable and further reduce nutrient loss, but currently, such technology requires high investments and is inaccessible to most farmers in poor countries. It is important to ensure that the practical advice developed for „best (good) agricultural practices ” is flexible and pragmatic in terms of incorporating new technologies and those more traditional ones relating to soil nutrient conservation technologies outlined above.

Fertilizer use technology includes several important steps: organizational, choice of machinery and equipment, their adjustment, and quality control. The following is essential to achieving the best possible success:

a) The method of application of the fertilizer should respect agronomic, economic and environmental requirements. Preference should be given to a method that directly incorporates fertilizer into the soil.

b) The fertilizer application should be such that the plant's root can easily access it.

c) The adopted method of application of the fertilizer depends on many factors such as type of application (spreading equipment), equipment setup, fertilizer quality (physical properties), conditions on the plot, application method, operator's skills, etc. All these factors should be known and involved if we want to get a good quality application.

Regardless of the low level of application of mineral fertilizers and manure per unit of agricultural land, relative to EU countries, the risk of diffuse pollution in Bosnia and Herzegovina should be taken seriously, as it may result from the inadequate application of mineral and organic fertilizers.

National strategic planning related to the control of nutrient pollution from agriculture requires the development of appropriate instruments and institutional arrangements to promote the adequate application of mineral and organic fertilizers and best available agricultural practices. This means that, regardless of the long road to EU membership, Bosnia and Herzegovina should adopt EU Nitrogen and Water Directives, in order to prevent further adverse effects on waters and aquatic ecosystems, bad practices, and applications, management, and manipulation of mineral and organic fertilizers.

4.4. Land Consolidation

Land consolidation (Ger. *Flurbereinigung*), agricultural and other types, is a complex activity that integrates spatial-planning, organizational, legal, economic and technical measures, in order to group, re-allocate spatially fragmented and mutually scattered plots of one property, preferably into one or several larger locations, with improvements to natural, economic and environmental conditions in an area. Land consolidation is very important today and is a proven instrument for the development of agriculture and rural areas. Although it is applied in other areas and to the land of different purposes (construction, water, forest land, etc.), agrarian development of an area in which land consolidation plays a particularly important role, so it can be said that in current practice, both in Bosnia and Herzegovina and other countries, land consolidation was primarily applied on agricultural land.

Although land consolidation is recognized and defined as a very complex and expensive agrarian, organizational, legal, economic and technical operation (Miladinović, 1997), it can be stated that its comprehensive implementation achieves multiple benefits, in the short and long term. Successful land consolidation results in an overall improvement in agriculture, an increase in productivity, efficiency and competitiveness of the entire agricultural sector.

It also leads to better land planning and management, job creation in agricultural regions, facilitates the inflow of private and public investments in this area, contributes to environmental protection, and enables the efficient management of natural resources.

Implementation conditions and models of land consolidation

The assessment of whether complex and costly land consolidation activities should be carried out is based on specific preconditions.

In that sense, land consolidation can be done:

a) If due to large scatterredness, fragmentariness and shape irregularity of land plots , the land cannot be rationally cultivated;

b) If due to existing conditions and property-rights status, or due to the large dispersion and irregular shape of land plots, it is not possible to organize production that provides for the profitability of investments in the areas where the public land reclamation works have been approved, carried out;

c) If the construction of major roads (or railways) and other facilities (embankments, canals, artificial lakes, etc.), or the regulation of major watercourses causes or will cause further fragmentation of existing land plots and disruption of the road and canal networks;

d) If, in order to create conditions for more rational land cultivation, it has been requested by the majority of landowners in the area proposed for land consolidation.

There are several names (Bogdanović, 1983) for different models of land consolidation such as conventional, moderate, radical, land consolidation based on crop rotation principle, shortened land consolidation, land consolidation for joint cultivation, land consolidation in the process of expropriation, land consolidation in urban regulation, integrated land consolidation and re-consolidation. In further systemization, the same author lists four types of land consolidation:

- Conventional, total or mandatory land consolidation,
- Working, productive or functional land consolidation,
- Partial land consolidation or re-allocation,
- Market or commercial land consolidation.

The new concept of land consolidation requires a versatile, multidisciplinary, comprehensive and inclusive approach, the integration of elements of agrarian development and the inclusion of village-city links. It is necessary to take account of geographical and cultural differences and the improvement of existing practices in this field. Local development plans and land use plans should serve as a basis for land consolidation.

Land consolidation should and must enable democracy in the participation of all actors and be driven by common interests. Therefore, it is necessary to provide an appropriate environment in which users will actively participate and take responsibility. The focus must be on the development of rural life, rather than on the primary production of goods and food. Society needs to define the new use of their resources, and therefore their land plots.

Accordingly, the basic elements of the new land consolidation concept should be (Čustović *et al.*, 2008):

- Division of responsibilities,
- User participation,
- Land consolidation as sale and purchase of land,
- Linking land consolidation to privatization and restitution,
- Linking land consolidation to rural development,
- Linking land consolidation to land registration.

Land consolidation in Bosnia and Herzegovina and the neighboring countries

In the former Socialist Republic of Bosnia and Herzegovina, and until 2016 in the post-Dayton Bosnia and Herzegovina, i.e. the Federation of Bosnia and Herzegovina, the Law on Land Consolidation was applied (SR BiH Official Gazette, nos. 24/85 and 26/90).

In 2016, a new Law on Land Consolidation was adopted in the Federation of Bosnia and Herzegovina (Federation of BiH Official Gazette, no. 57/16), while Republika Srpska continued to apply the old law.

According to the basic concept of both laws, consolidation of agricultural and other land is done in order to enable more economical cultivation and utilization of land and perform other works involving regulation and reclamation of land, by arranging land areas and creating bigger and more regular land plots, by grouping them and grouping land estates.

There is a significant difference between these laws in terms of adapting the new law to the constitutional and legal system of post - Dayton Bosnia and Herzegovina, as well as to the principles of market economy and different property - rights relationships, with greater transparency and democratic nature of overall procedures.

Historically, since the beginning of the implementation of land consolidation, its major objective has been to consolidate agricultural holdings into as few properly shaped plots as possible, in order to improve primary agricultural production and enhance its development. The development of agriculture is one of the essential factors of rural development and rural life.

In developed countries, the countryside has long been regarded as a training ground intended solely for agricultural production. For this reason, in Western European countries, land consolidation also serves as a tool for comprehensive rural development. The new concept of rural development treats land consolidation as a complex project that, among other things, aims at the permanent reconstruction and improvement of the rural community. In many countries of Central and Eastern Europe, rural living conditions have deteriorated during the transition period. High unemployment and poor infrastructure have made villages less attractive places to live in. To improve the situation, a large number of land consolidation pilot projects have been implemented to enable transition countries to initiate land consolidation on their own terms and improve agricultural production and quality of life in the countryside.

Land consolidation project

The land consolidation project should satisfy the general and local interest in the area of its implementation and must comply with the spatial and urban plans.

The territorial organization is a significant segment of land regulation that is implemented in coordination with the spatial plan of a given area (Ristić and Vlahinić, 1983).

Optimal disposition of the field road network and other infrastructure, production boards with the landscape design of the space, and the achievement of environmental protection goals are just some elements of the organization of the territory, i.e. spatial planning in the modern sense.

As a rule, the land consolidation project is developed based on valid municipal spatial planning documents, which, in their current state and planned projections, include the following:

- Areas of intensive agricultural production,
- Areas used periodically for agricultural production,

- Areas of intensive forestry,
- Future construction areas,
- Areas intended for recreation,
- Protected areas due to their high environmental value,
- Areas planned for infrastructure facilities.

For further elaboration of the land consolidation project, it is necessary to collect data on land use, canal and road networks, land position, shelterbelts, the structure of estates, size and shape of plots, settlement regulation, etc.

Geodetic plans of 1:1000, 1:2500, or 1:5000 scale are used as the graphic basis for the development of the land consolidation project.

The basic content of the land consolidation project consists of three units:

- Project of geodetic works,
- Project of the road network, and
- Project of the canal or hydromelioration network.

The focus of the land consolidation project is particularly placed on the production plot. It is necessary to achieve not only the largest possible production plots but also their regular shape, with the closest possible location to the economic yard (Lukić, 1985). In this sense, the main elements of the production parcel include:

- size,
- length and width, i.e. shape, and
- distance from the economic yard.

Consequently, agricultural production is influenced, inter alia, by the size, shape and orientation of the plots (Lukić, 1985). The optimal shape of the agricultural plot enables efficient cultivation with the agricultural machinery that is in use nowadays. The orientation of the plots is also an important factor for agricultural production. On hilly terrain, production plots should be aligned with isohypses, in order to reduce erosive effects of water. On flat terrain, the most favorable orientation for sowing and ploughing is south-northth, as scientific researches have proven.

The size of the production plot (Figure 33.) is a factor that significantly influences the cost of agricultural production (Vukotić, 1988). The number of person-hours per year required for cultivating a land plot whose area is increased from 0.25 ha to 4 ha is smaller by 33% to 63%, depending on the crop being sown. Longer plots are more favorable compared to shorter ones, as the number of the machine turns is smaller.

An increase in length from 100 to 400 m reduces the total work time by 3 to 34 hour/ha, depending on the crop (Figure 34.). The distance of the plot from the economic yard considerably affects the production cost, and with the increase in distance the cost of transport and labor increases as well. An increase in distance by 1 km in small plots (0.25 ha) causes an increase in total working time by 7 to 18 hours/ha, depending on the crop.

In the process of land consolidation, production plots are formed after designing the road and canal network. The distance between the road and canal networks as well as their position in space determines the length and width of the production panel (Ivković *et al.*, 2008). Production panels of 250 - 300 m x 800 - 1000 m, or 20 - 30 hectares of surface are formed, which is typical of large lowland complexes.

When designing a road network, in addition to information on the composition of the terrain and its altitude, it is necessary to know the structure and method of cultivation of particular crops; weight, width, direction and frequency of movement of agricultural machinery; previous structure of estate, etc.

In addition to the size and shape of each production plot, its cadastral use type, class and soil bonity are of particular importance. According to modern standards and current legislation, the cadastral land classification includes the establishment of cadastral culture and class separately for each cadastral plot within one cadastral municipality, while soil rating includes the determination of soil fertility based on its natural properties and other natural conditions for production, regardless of the existing way of its use.

The cadastral class (Begić *et al.*, 1991) is a product of the interaction of natural and economic conditions of agricultural production. Natural and economic conditions include natural properties of the soil, position and exposure, water regime of the soil, climate, and distance from the market and accessibility of the plot. Soil quality rating determines the productive potential of the soil, i.e. its fertility regardless of its use.

Consideration is also given to the broader hydro-amelioration works undertaken for the construction of hydro-power plants, regulation of land and infrastructure, as well as drainage. Such interventions funded by the wider social community make permanent changes to the soil rating.

Regulation of agricultural land in a broad sense encompasses a wide range of various technical, agro-technical and technological interventions aimed at creating conditions for rational land use in modern agricultural production, states Vlahinić (1981). According to the cited author, these interventions include two basic components: hydromelioration and other measures of regulation. In most cases, hydromelioration is the most complex and most expensive intervention in the land regulation, states the same author. They are often conditional on other regulation measures. In view of the previous regulation of the soil water regime, hydromelioration includes interventions: in space and in soil.

Land consolidation and protection of the environment

Agriculture and the environment can no longer be considered separately, as the ecological boundaries of intensive agricultural production have become clearly visible. In other words, the interests of agriculture come into conflict with the environment, and additionally, it contradicts the interests in the reconstruction of settlements, construction of infrastructure and urbanization, so the role of land consolidation, therefore, becomes increasingly important for the reconciliation of all these different interests.

Considering environmental protection, planning, the technical, financial and legal potential of land consolidation should be utilized in order to preserve the ecological potential of a given area; implement an agrarian policy that is closely related to environmental protection, on the sustainable management matrix, and reconcile the contrast between environmental and agricultural interests.

FIGURE 33. *Fragmented plots of a private estate – Ljubinje (Photo: H. Čustović)*

FIGURE 34. *Regulated plots (consolidated) on a public estate*

DEVELOPMENT OF RURAL AREAS THROUGH THE LAND CONSOLIDATION PROCESS IN THE MUNICIPALITY OF RAVNO (EXAMPLE)

The total area of the Municipality of Ravno is 32,303 hectares, of which 20,708 hectares or 64% is agricultural land. Areas of agricultural land by crops recorded in the municipality cadaster are as follows: ploughfields and gardens 10,322 hectares, pastures 6,760 hectares, vineyards 1,615 hectares, orchards 1,012 hectares and meadows 999 hectares. The proximity of the river Trebišnjica, developed irrigation system and groundwater level ensure quality irrigation of agricultural land in Popovo field. Thanks to the wide mosaic of soil types, as well as microclimate and geographical position, the agricultural product offer is characterized by a wide range and diversity. The predominant branches of agricultural production include viticulture, fruit and vegetable growing, animal husbandry, and the area is also suitable for growing vegetables and flowers in greenhouses. In the „Development Strategy of the Municipality of Ravno“, rural development is becoming an increasingly important element of agricultural policy, especially the creation and implementation of measures to assist people in generating additional income in agricultural production. In order to create a sustainable agricultural sector with larger and more effective agricultural production, that will be competitive in the domestic and international markets, and based on the strategic documents of the Municipality of Ravno that promote the natural potential for agricultural development, especially in terms of increasing the size of land estates, a pilot project on agricultural land consolidation was launched. Table 14. lists the average land plots by cadastral municipalities, which indicate the actual and urgent need for land consolidation in the Municipality of Ravno.

Figure 37. shows the site of Donja Luka which has been identified as a project area in accordance with the general interest and referendum through which the participants expressed their desire to implement the land consolidation. Donja Luka is bordered by the natural line of the limestone massif on the south and south-west side, and by the river Trebišnjica and an embankment protecting the area from floods on the north side. It should be noted that this site is characterized by considerable homogeneity of the soil on most of the surface designated for the implementation of the land consolidation pilot project.

The area of land included in the consolidation at this site is 101.5 hectares, with 744 plots and 121 landowners. The average number of plots per landowner is 6.15, while the average area of the cadastral plot is 0.13 hectares.

TABLE 14. *The average area by cadastral municipalities for the cadastral use types of field, meadow, vineyard and orchard*[29]

Name of cadastral municipality	Number of plots	Average parcel area in ha	Number of users	Average size of estate in ha	Average number of parcels per user
Čavaš	1,279	0.26	379	0.88	3.4
Čvaljina	1,842	0.15	196	1.42	9.4
Dvrsnica	744	0.16	132	0.91	5.6
Grmljani	1,567	0.21	126	2.59	12.4
Kotezi	4,461	0.13	299	1.92	14.9
Orašje	1,271	0.21	196	1.36	6.5
Poljice Popovo	1,464	0.13	138	1.34	10.6
Ravno	3,280	0.09	199	1.53	16.5
Sedlari	1,172	0.17	137	1.46	8.6
Trebimlja	4,220	0.15	509	1.24	8.3
Trnčina	1,973	0.15	242	1.22	8.2
Veličani	3,667	0.22	358	2.28	10.2
Velja Međa	1,425	0.14	355	0.58	4.0
Zavala	1,161	0.14	146	1.14	8.0
Dračevo	2,192	0.32	293	2.40	7.5
Drijenjani	998	0.37	287	1.27	3.5
Dubljani	970	0.29	88	3.25	11.0
Mrkonjići	1,000	0.25	164	1.55	6.1
Tulje	764	0.31	89	2.64	8.6

[29] Čustović *et al.* (2008): Feasibility study of land consolidation in Popovo field

FIGURE 35. *Popovo field (Photo: H. Čustović)*

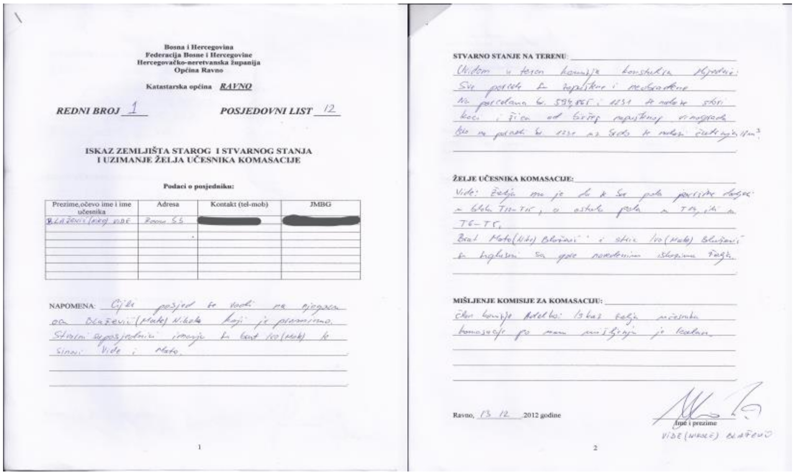
Land consolidation phases

The prerequisite for successful land consolidation is to determine the legal and actual status of the land, and in this respect, all data on the shape, size and use of land are collected.

After the approval of the scope of land consolidation by the Municipal Council of the Municipality of Ravno, the preparation of project documentation began and it included geodetic surveying, the definition of planes, planning of road and canal networks, planning of drainage canals. Creating a quality project document is the basis for commencing the land consolidation process.

After the reconciliation and completion of the project documentation, the realization of the project began. The consolidation process was carried out in three phases over a period of three years, and in accordance with the Law on Land Consolidation (Official Gazette of SR BiH, nos. 24/85 and 26/90).

The first phase of the land consolidation began with establishing the previous situation and collecting desires voiced by the landowners (Figure 36.). During this phase, the land consolidation committee met with the landowners to present the cadastral plans showing the planned planes and supporting infrastructure, as well as the position of their plots within the consolidation scope. During the meetings with the landowners, a document dubbed „Statement of the previous situation and the desires of the participants in land consolidation“ was completed. The owners' wishes regarding the position of the newly formed plot were entered into this document. The document was then signed by the committee representative and the landowners.



Bosna i Hercegovina
Federacija Bosne i Hercegovine
Hercegovačko-neretvanska županija
Općina Ravno

Katastarska općina RAVNO

REDNI BROJ 1 POSJEDOVNI LIST 12

ISKAZ ZEMLJIŠTA STAROG I STVARNOG STANJA
I UZIMANJE ŽELJA UČESNIKA KOMASACIJE

Podaci o posjedniku:

Prezime,očevo ime i ime učesnika	Adresa	Kontakt (tel-mob)	JMBG
[illegible]	[illegible]	[redacted]	[redacted]

NAPOMENA: [illegible]

1

STVARNO STANJE NA TERENU: [illegible]

ŽELJE UČESNIKA KOMASACIJE: [illegible]

MIŠLJENJE KOMISIJE ZA KOMASACIJU: [illegible]

Ravno, 13. 12. 2012 godine

Ime i prezime

2

FIGURE 36. *The „Statement of the previous situation and the desires of the participants in land consolidation“*[30]

In the area where land consolidation was carried out, there were no long-standing plantations or infrastructural facilities, so only the value of agricultural land was appraised.

An expert in the area of agriculture did land value appraisal.

After the land appraisal, the allocation of land to the participants began. During the allocation of land, the areas were reduced by 2% per landowner for the purpose of building a quality road and canal network. The land allocation was done respecting the realistic desires of the participants of land consolidation. The statement of the new situation was presented to the public. After reviewing the new situation, the participants signed a document called the „Statement of the new situation“ stating whether they agreed with or objected to the new allocation. After making the statement public, the participants had the right to complain in writing within 15 days. After the complaints received were resolved, the second phase of land consolidation began.

The second phase of land consolidation began with the final drafting of the statement of the new situation and geodetic surveys consisting of staking out new boards and road network, as well as staking out boundary points and marking them with permanent markers. After the surveying, conclusions were made concerning the acquisition of temporary possession that were delivered to the owners. All owners were provided with temporary possession and a record of that was made.

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[30] Municipality of Ravno

In the final part of the land consolidation, **the third phase**, Decisions were made on the allocation of new plots and the new allotment was presented to the public. The final entry into possession was performed for all participants, followed by the implementation of a new allotment in the cadastral records.

Results of land consolidation

Land consolidation in the area of the Municipality of Ravno and the Donja Luka site contributed to a significant decrease in the total number of plots, further resulting in a decrease in the average number of plots per landowner and an increase in the average size of plots as shown below:

	Before land consolidation	After land consolidation
Number of plots	744	127
Number of landowners	121	116
Average number of plots /owner	6.15	1.1
Average size of plot	0.13 ha	0.80 ha

In addition to the visible metric indicators, it should be noted that the newly formed plots were more regular in shape and had an access road, which is visible in Figure 37. Lack of road communications is the major negative feature of land estates in the Municipality of Ravno. The distance between plots in one estate ranges from 1 to 3 km. The construction of new access roads will significantly reduce the production cost, which will lead to more profitable agricultural production.

FIGURE 37. *Donja Luka site – before and after land consolidation*[31]

In addition, the land consolidation process has contributed to the education of both the direct participants in the process and the farmers who were skeptical about the outcome of the process until the moment of implementation and first visible results. During the land consolidation process, a good environment and trust were built between the landowners and the local self-government. By consolidating the land, the existing plots gained greater monetary value thanks to the area and the possibility of more competitive production.

Land consolidation at the site of Donja Luka is the most significant step towards sustainable rural development of the Municipality of Ravno.

This land consolidation was carried out on a small area of agricultural land in the Popovo field, but due to exceptional results, it aroused great interest and willingness of other farmers in different cadastral municipalities to launch new land consolidation projects.

[31] Municipality of Ravno

This successfully completed agrarian measure has contributed to the resumption of active agricultural production by many landowners who had long since left the Municipality of Ravno. One part of the landowners expressed their willingness to cede their land to the state or other persons interested in farming.

Improving agricultural production in Bosnia and Herzegovina is essential for the return of young people who still want who still want to engage in and make a living from agricultural production. Building the legal system of the Federation of Bosnia and Herzegovina implies its regulation as well, all aimed at improving market policy and protecting the public interests, as well as harmonizing it with EU regulations. The importance of agricultural land as a natural resource and asset of general interest has manifested itself in the European Union by member countries adopting a specific Rulebook aimed at introducing integrated rural and market policies, as well as pricing policies under the Common Agricultural Policy, and promoting all the elements of agricultural development through increased participation of local communities. The new policy, linked to agrarian activities and reform of its structures, aims inter alia to improve working and living conditions, and to provide equal opportunities for all farmers.

The old Law on Land Consolidation (Official Gazette of SR BiH, no. 24/85) did not fully correspond to the new policy related to agrarian activities and the reform of its structures. For these reasons, the new Law on Land Consolidation of the Federation of Bosnia and Herzegovina was adopted (Official Gazette of the Federation of BiH, no. 57/16). The new law greatly contributes to and facilitates land consolidation and its funding.

4.5. MICRO-RESERVOIRS

The construction of micro-reservoirs can have a very beneficial effect on people's lives, especially in mountainous and karstic areas. Micro-reservoirs not only reduce the risk of floods and erosion in the downstream parts of the catchment, but can also be used for the revitalization of hilly-mountainous areas, for the development of rural tourism, fish farming, animal husbandry, irrigation, water supply, and fire protection.

Mountain micro-reservoirs can be built not only on watercourses but also on gullies. The purpose is to catch surface water (water harvesting) and prevent their uncontrolled runoff. The construction of agricultural micro-reservoirs in the mountainous regions of Bosnia and Herzegovina would largely contribute to the improvement of livestock production along with the production of feed, vegetables, and other types of mixed farm production.

This could initiate and boost the revitalization of villages and rural areas in general, which would in many respects contribute to more harmonious development and better living conditions for people in both the countryside and the towns.

FIGURE 38. *An example of micro-reservoir (Photo: M. Ljuša)*

The most important role of micro-reservoirs is reflected in the fact that they directly contribute not only to water wave amortization and flood risk reduction, but also to the improvement of conditions for the surrounding flora and fauna through soil and water conservation in the catchment, with reforestation occurring as a spontaneous or supported phenomenon, and considerably mitigated erosion.

When it comes to size, micro-reservoirs can be built in a very wide range of volume, from very small ones whose volume is similar to slightly larger puddles, to those whose volume is measured in tens of thousands of m^3. In addition to concrete, earthen dams are very often built, with volume varying from one hundred to ten or more thousand m^3, while the height of such dams reaches 5 to 10 m. The mean ratio of the micro-reservoir/dam is approximately 3.5:1, maximum 5.6:1, minimum 2.2:1 (Vlahinić, 2002; 2003).

Today's technical means enable their quick and relatively inexpensive construction, and on the other hand, geological, geomorphological and relief conditions in Bosnia and Herzegovina are naturally predisposed for the construction of such micro-reservoirs. Large areas of Bosnia and Herzegovina are covered with major deposits of tertiary clays, which are a very suitable building and hydro-insulating material for the construction of small earthen dams and the waterproofing of reservoirs situated in such terrains.

Well-chosen topographic conditions should ensure cost-effective construction, given that construction cost depends on the reservoir's volume, as well as the ration of the dam volume and the reservoir volume. The reservoir feed must be provided with waters from the catchment, which must not be polluted. Earth material for the dam must be in the proximity of the dam site in order to facilitate the construction of a stable and leak-proof facility. All such reservoirs must be provided with adequate overflow devices for the evacuation of high water, as well as with bottom outlets for discharge for maintenance and cleaning purposes. They can be built not only on rivers and streams but also on gullies from where only the surface runoff from its basin can be expected and predicted with reasonable certainty based on agro-hydrological balance.

Such micro-reservoirs are key facilities for revitalizing hilly and mountainous regions as well as for retaining people in these often harsh living conditions. Their use value in these regions is manifold: water supply to people and livestock, irrigation, tourism, fish farming, fire protection, and other purposes. In addition, micro-reservoirs serve to reduce water waves and floods in the downstream stretches of a narrow valley, to prolong the life of the downstream large accumulations, to reduce damage, retain pollutants and support aquifer restoration. It has been observed in some areas that natural sources, that have long since dried up, have begun to flow again after the construction of micro-reservoirs and the implementation of conservation measures in the catchment. Such facilities must be protected by a fence so as not to be damaged by livestock, and it would be good to protect the catchment plane, depending on the size of the collection area.

The cost of construction of these facilities, considering the technologies available, can be very different, but the safety of the constructed facilities (dams) and environmental impact are always in the first place.

However, James Marple (North Caroline - USA) has some interesting observations concerning the need to simplify the design and construction of micro-reservoirs, which is opposed to „over-engineering“. Non-engineers working to capture and use rainwater can build a micro-reservoir of 4,500 m^3 in volume for about 100 $. Civil engineers raised these costs to 5,500 $ (55 times more) to achieve the same volume of 4,500 m^3 in Southern California. These striking differences indicate the need to develop a manual for the inexpensive construction of such facilities, which must be adapted to the adverse effects that may result from their breakdown.

4.6. Making A Gathering Ploughing Terrace Along A Contour Line (Isohypse)

Predominant terrains in Bosnia and Herzegovina include hilly-mountainous and karstic regions that account for more than two-thirds of the total area. Approximately 80% of the land area is on a smaller or larger slope. Significant areas have a pronounced inclination, which along with other factors (geological substrate, pedological formations, relief energy (slope and exposure), the density of hydrographic network, climate, precipitation regime, vegetation cover, tillage, anthropogenic factors), are conducive to the development of various forms of erosion processes. Of the total area of Bosnia and Herzegovina amounting to 51,129 km^2, erosion processes affect an area of 45,574 km^2 or 89%.

When it comes to the occurrence and development of erosion processes, one of the significant factors is certainly the tillage method. Appropriate soil tillage and the use of crops appropriate for steep terrains susceptible to erosion processes is a very efficient counter-erosion measure. According to Šarić and Sijahović (2017), slopes, especially those exceeding 10%, should not be used for growing crops of thin assemblage (maize, potato, etc.), which open the way to erosion and increase soil degradation and loss by 10 to 50 times more than the crops of dense assemblage. The same authors note the importance of contour ploughing, stating that the land on the slopes must be ploughed along the isohypses because in this way, every back furrow (ridge) and dead furrow will be an obstacle to the flow of water; this reduces the soil washing by 50 - 95% compared to the ploughing along the slope, and at the same time increases the amount of water absorbed by the soil from rain and snow.

This method of farming also has a positive effect on the reduction of downslope runoff.

The construction of terraces on slopes has also proven to be a very efficient counter-erosion measure.

Slope terracing is a common practice in various parts of the world. Although it is not known where, how, or why the first terraces were built, their application has spread throughout the world thus becoming one of the major methods of transforming steep slopes into fertile and accessible cultivation areas. The beauty and value of all terraced landscapes lie in the fact that the terraces are built in harmony with the particular location in which they are situated. The ways of their use vary from place to place, as they are adjusted to the natural conditions, people and their needs. Despite the great value that terraces represent in terms of heritage, tourism and economy, many of them worldwide have been abandoned for years.

FIGURE 39. *Back-furrowed terraces - Dobro polje in Gacko (Photo: H. Čustović)*

In some cases, tillage is highly questionable unless terracing is done beforehand. According to Kisić *et al.* (2000), on colluvial soils and rendzinas, i.e. soil types with a high risk of erosion, any tillage on slopes exceeding 6% inclination is highly questionable without prior terracing.

Applied plowing techniques can make a significant contribution to minimizing erosion processes on the terraces. The plowing technique itself can have a significant impact on the intensity of erosion processes. One of the techniques to be applied in this case is the so-called ploughing in runs; it is the most widespread plowing technique and is performed by single bottom plow tractors that always plow to the right. Ploughing in runs is divided into gathering and casting methods.

„Gathering requires for the ploughing to begin in the center of the field. The first and second furrow slices fall on top of each other, and the ploughing continues towards the edges of the field. This method leaves a small elevation – „gathering" at the center of the field. To avoid this elevation, the first furrow should be plowed narrower and shallower, and the second wider and deeper, and after that, the plooghing continues at the desired depth. The casting pattern begins first at the right-hand side of the field, relative to the plowing direction, and continues on the left side. After that, plowing continues towards the center of the field, until a canal called „cast" is left there, Komljenović (2012).

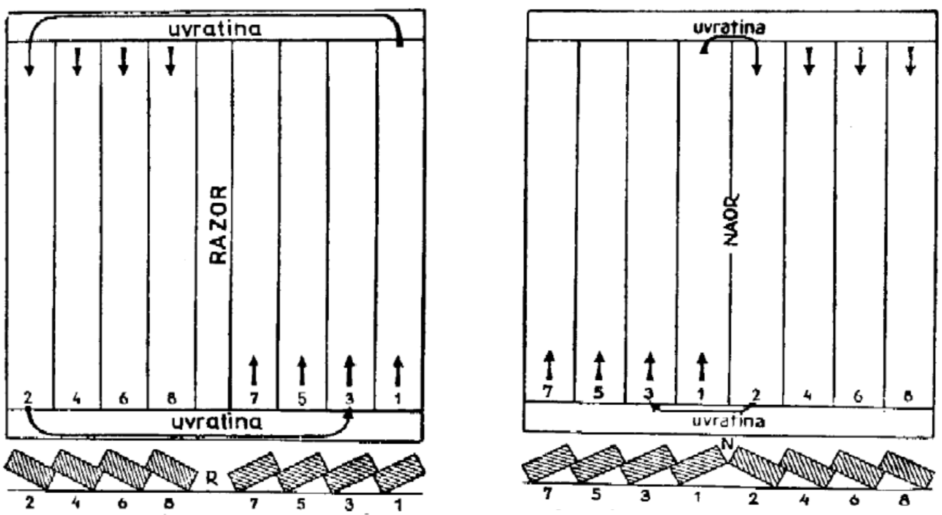

DIAGRAM 4. *Casting pattern* *Gathering pattern*[32]

[32]http://www.fazos.unios.hr/upload/documents/Osnove%20Bilinogojstva%20004%20(osnovna%20obrada%20tla).pdf

Combating erosion processes, in addition to back furrowing against the slope, includes other forms of defense as well. One of the most important forms of erosion control is the construction of new terraces. It also happens that the plots lying on the slope are contour farmed by being constantly ploughed in gathering pattern to the lower side (downstream). In this case, there is a gradual relocation (stripping) of soil and the formation of shapes that are irresistibly reminiscent of terraces. Farmers create such gathering-ploughed terraces spontaneously and gradually, without any project documentation. Most such ploughed terraces in Bosnia and Herzegovina are found in its mountainous regions. The terraces created in this way have a smaller slope compared to the original land plots they were made on, as well as a higher capacity to retain and infiltrate water in the soil profile.

Therefore, by long-term ploughing the soil material is being transferred to the lower part of the plot, so that the accumulation of material creates a higher part of the plot edge, which is again below the initial lower part of the adjacent plot. On the cross-section, on the lower part of the terraced plateau, plough terrace has its slope. It is formed by plowing in gathering pattern and is located above the next terrace. The height difference between the two adjacent plough terraces is conditioned by the height of the slope.

It depends on the original slope angle, the energy of the soil, the degree of looseness of the geological substrate, and finally, it depends on the age of the plough terrace. The heights of the slopes of plough terraces are different. Normally they range from 0.5 to 1.5 m.

The slope angle of the newly created terrace is generally no higher than 5 to 7%. In shallow soils whose solum is under 0.8 m in depth, the height of the slope is up to 0.5 m. Medium deep soils with a solum of up to 1.2 m have a slope of about 1.0 m on average, while deep soils with a solum depth of under 1.6 m have a slope of up to 1.5 m.

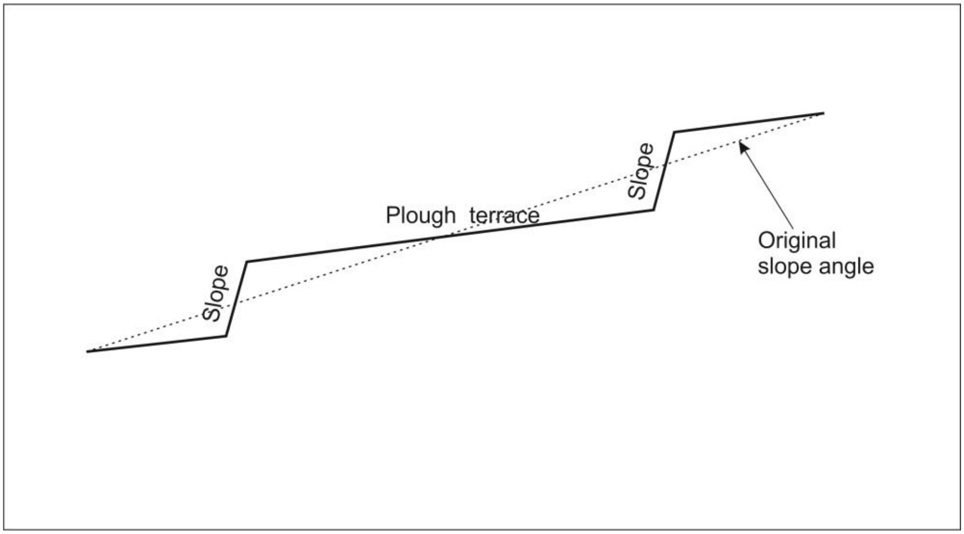

DIAGRAM 5. *Plough terrace*

4.7. AGROFORESTRY

A simple definition of agroforestry could be that it is a deliberate combination or fusion of agriculture and woody crops helping creation of sustainable farm systems for crop and livestock production. It is a combination of traditional agriculture and conventional forestry, hence the name agroforestry.

There are three main types of agroforestry systems (FAO, 2015):

1. Agrisilvicultural systems are a combination of crops and trees, such as alley cropping or homegardens.
2. Silvopastoral systems combine forestry and grazing of domesticated animals on pastures, rangelands, or on-farm.
3. The three elements, namely trees, animals and crops, can be integrated into which are called agrosilvopastoral systems and are illustrated by homegardens involving animals as well as scattered trees on croplands used for grazing after harvests.

A model of such an agroforestry concept is shown in Figure 40.

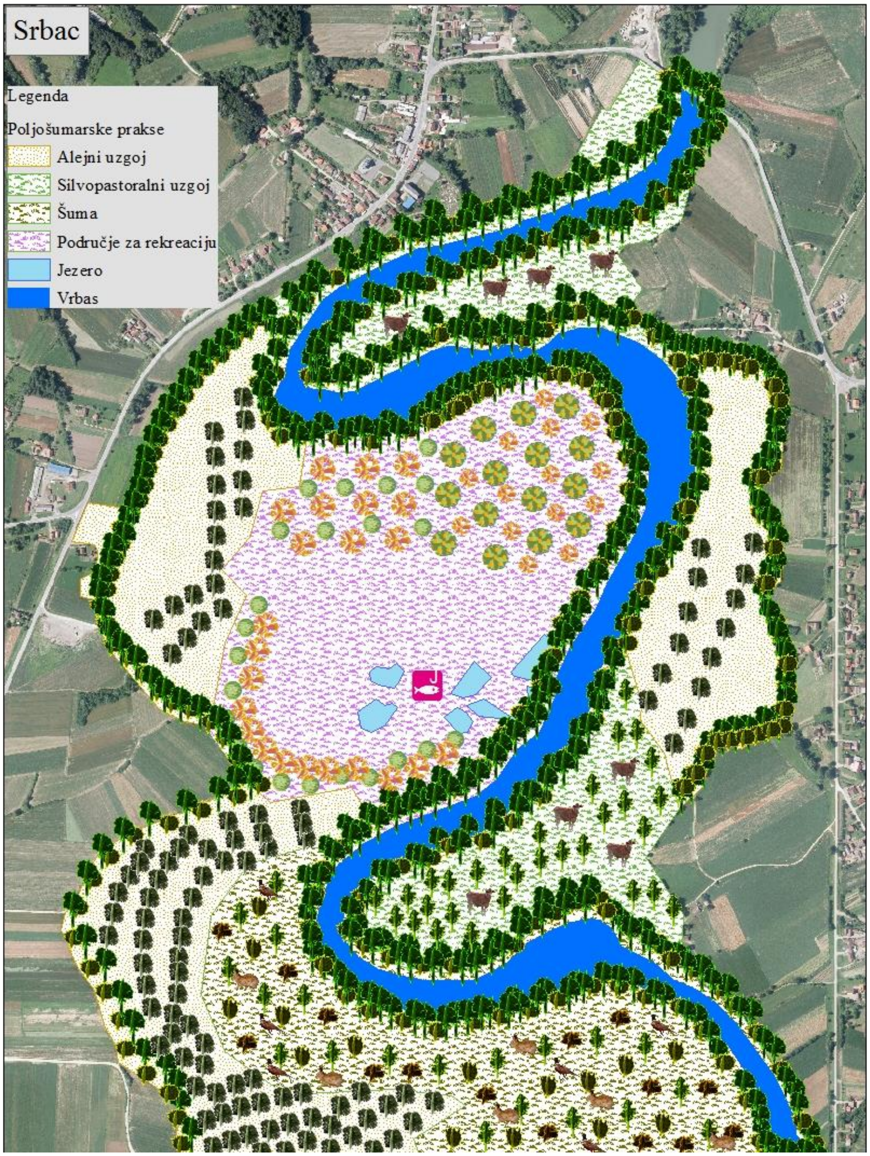

FIGURE 40. *The model of spatial planning in the Municipality of Srbac encompasses an approximate division of space according to uses that overlap, which include: 1) forest buffer zone, 2) alley cultivation, 3) silvopastoral cultivation, 4) hunting grounds, and 5) recreation areas.*[33]

Alley cultivation
Recreation areas
Silvopastoral cultivation
Lake
Forest
Vrbas River

[33] H. Čustović 2017. Agroforestry in the Vrbas River Basin – Study.

In Europe, the United States of America, agroforestry practices are grouped into five categories: alley cropping systems, silvopastoral (forest-pasture) systems, forest farm system, coastal forest buffer strips, windbreaks, and forest areas for special purposes (game, forest fruits – mushrooms, medicinal herbs, juices, resins, etc.).

Agroforestry systems are multifunctional systems that provide a full range of economic, socio-cultural, and environmental benefits (FAO, 2017). These systems can be very useful for small-scale producers because of the variety of products and services on limited land areas. As a measure, agroforestry is linked to the attainment of SDGs nos. 1 (No poverty), 2 (No hunger), 12 (Responsible consumption and production) and 15 (Conservation of life on Earth). The importance of agroforestry, inter alia, is reflected in the fact that this approach can help to restore degraded forests and agricultural land, which further contribute to the restoration of the landscape.

However, agroforestry can be a complex measure requiring, among other things, education of agricultural producers. The future of agroforestry in our conditions depends on three key factors: i) research, dissemination of information and understanding of this approach; ii) agroforestry development policy, and iii) protection and conservation rural areas. It involves multiple benefits that integrate woody and agricultural crops in such a way that the system should demonstrate an increase in the potential of agriculture and forestry or the cultivation of woody crops, fruit trees and the like, and contribute to the protection of the environment in terms of the regulation of quality of soil, water and air, as well as the preservation of cultural heritage. In addition, such a system of farms is in direct coordination with adaptation measures to climate change which becomes an increasingly important issue.

Design and management systems for achieving maximum productivity

The interaction between forest and non-forest components in agroforestry may be positive, negative and neutral, and the productivity of this system is the result of these interactions. The agroforestry system should be designed to optimize resource capacity by maximizing positive interactions and minimizing negative ones. A proper selection of forest-woody crops and field and fodder crops for human and animal nutrition is very important for providing farmers with important prerequisites in terms of quantity, quality, and economic sustainability.

It is also important to consider the potential interaction between different plant species. The best tree species for an agroforestry system should support and enable the development of field and fodder crops. The best forest-fruit trees are those which develop a deep root that allows the extraction of nutrients and water into the surface layers of the soil. This enables the creation of microclimates for the development of the surrounding vegetation and an increase in biodiversity for the development of various organisms in general.

Spatial zoning and plant arrangement have a major impact on productivity (Figure 41.). Properly distributed and oriented plants have more space for mutual interaction compared to the crops and trees planted without proper arrangement. In the moderate climate belt, row orientation should be mainly north-south, as this is considered to be the most effective system for providing sunlight to the cultivated plants and pastures.

Within an agroforestry system, the productivity of each of the cultivated components can be subject to manipulation of management practices to include pruning, weed growth, and development control aas well as animal damage protection. The tree density control along with pruning provides the necessary amount of light for the cultivated crops or grassland. This is also very important for forest trees as it has a direct impact on the quality of wood. The inter-row tillage results in cutting off the laterally spreading tree roots that contributes to the reduction of the sub-surface competition for water and nutrients among between-the-row crops, thus extending the profitability of cultivated field and fodder crops. Early weed control is very important for reducing competition and the plastic sheet is often used to reduce the pressure of weeds on newly planted forest seedlings.

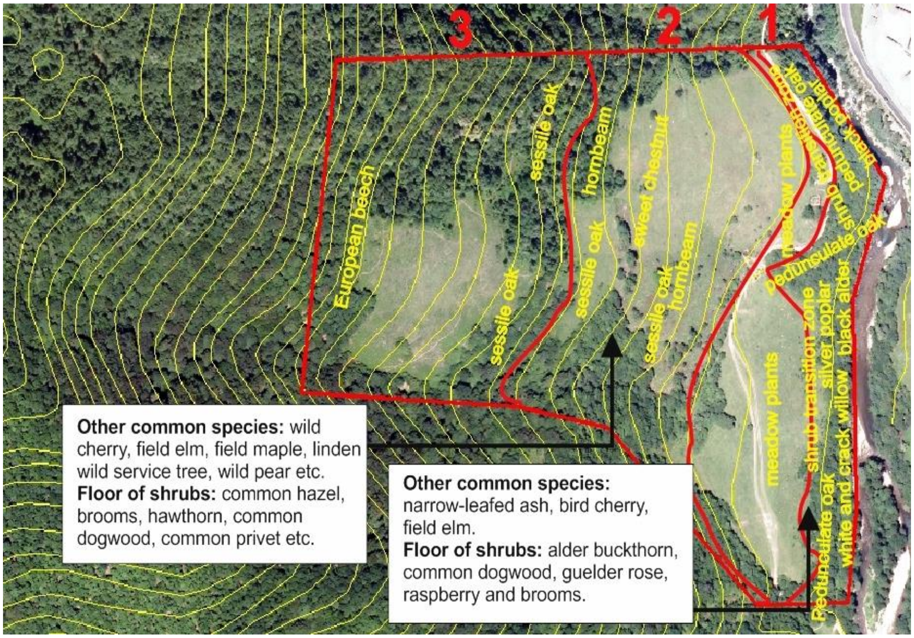

FIGURE 41. *Proposed plant species for erosion control*[34]

4.8. Maintenance And Improvement Of Meadows And Pastures

State of pastures

The quality and potential of pastures play a very important role in the development of livestock production. Since Bosnia and Herzegovina is a mountainous country, animal husbandry is one of the most important agricultural activities. It has always played a major role in the survival of the population in this area. This is especially true for the Dinaric and karst areas extending from south-west to southeast Bosnia and Herzegovina, which is over 60% karstic in character.

For pastures can be said to be anthropogenic by its character, with livestock grazing having a decisive influence on their formation. Man has systematically influenced the suppression of forest vegetation and the formation of grassland. It is a centuries' old tradition, conditioned by livestock type of land management, with the successive conversion of forestland into rocky pastures or pastures on shallow soils and sloping terrains.

[34] H. Čustović. 2017. Agroforestry in the Vrbas River Basin – Study.

Bosnia and Herzegovina is rich in natural pastures, grassland and meadows, which is important to know from the standpoint of feeding livestock, especially if it is known it is cheaper compared to any other animal breeding and feeding methods, especially the stationary one. It is both a more humane form of livestock farming and a form of organic farming. Feeding on pastures ensures high-quality food, generally rich in micro and macro elements.

Pastures in mountainous regions are important for nomadic livestock farming, especially for sheep farming. Grazing is important for balancing uneven summer and winter nutrition in extensive livestock farming. This is particularly important in sheep farming, especially in the early period, where sheep spend nearly half of the year grazing (May through October), and the other half feeding on scarce winter diet, which occasionally includes dray forest life, thus proving extreme scarcity of winter food. Everything is focused on summertime grazing, including milk productivity, fattening, and weight gain. Sheep and lambs come to the mountain pastures at the most suitable time for milk yield of sheep, i.e. weight gain of weaned lambs, and in the fall, ewes in the period of cessation of lactation, castrated sheeps and other redundant heads, that need to „removed from the winter feeding“ on which only breeding and young animals remain. This way of exploiting sheep depends largely on the quality of the mountain pastures.

Good mountain pastures produce good results, while poor pastures cannot provide the livestock with the minimum nutrition required for high yields of milk, meat and wool. Because of this, livestock farmers having this kind of pastures are forced to move the sheep towards higher altitudes, changing locations (nomadic concept).

Most of our mountain pastures, sheep farming regions, are rather poor due to the lack of care, weeds, poor quality grass of the Nardus (*Nardus stricta* L.*)* type. In our hilly-mountainous regions, the departure of sheep from home in search of grazing land begins in early summer, and they return to the village in early winter. Therefore, pasture management and maintenance, care, and balanced exploitation have always been of particular importance for the survival of the population and the sustainability of this highly delicate ecosystem of Bosnia and Herzegovina, as well as of the entire Dinaric region. The abandonment of this type of livestock farming is a result of economic and social events (war) on a broad scale, especially in rural areas.

It has led to disruptions in the management of these areas, with successions, changes in biodiversity, and a whole range of changes in the appearance of the traditional landscape, established thanks to the anthropogenic impact associated with agricultural production, cultivation of land, and livestock production.

Determining the right timing for grazing is very important, especially in cattle farming. If the cattle are let to graze early, there will not be enough food, and very intensive trampling occurs during the search for food that is scarce. If cattle come out for grazing late, that is also unfavorable, as the plants are of poor quality at this stage of development. Pastures should be relatively dry, below the water retention capacity of the soil, and grazing should end at least twenty days prior to the first frosts. Additionally, wet pastures are very rich in parasites, which can cause animal diseases. Taller grass of 15 - 20 cm is more favorable as parasites develop at lower positions. About 100 m^2 of good pastures can provide food for one animal for one day.

Taking care of pasture maintenance must be continuous. This primarily refers to fertilization and surface cultivation, i.e. harrowing (scraping) of pastures, overseeding, and suppressing weeds and invasive plants.

The system of rotation pasture is often used in cattle breeding as it allows for pasture restoration, prevents weed development, reduces trampling, and improves grass quality. This is the best way to manage pastures in a planned manner, with rotational grazing areas being separated by fences made of wood, wire, stone, e.g. in Dinarides, or natural hedges, etc.

How long will cattle be kept at one location – rotational grazing area, depends on several factors such as soil properties, location and relief position, length of vegetation period, the time it takes for grass to recover on rotational grazing area. According to the experience of some cattle farmers in Serbia, cattle are kept for two days on rotation grazing areas situated on valley and hilly soils, while in mountainous areas grazing length can be four to five days[35].

[35] http://www.agronews.rs/pasnjaci-vazan-izvor-stocne-hrane/

FIGURE 42. *Rotation pastures (Photo: H. Čustović)*

According to research in the BBio Project Study – „Sustainable development of border areas through the preservation of indigenous breeds and the establishment of gene-centers in Buhovo and Biokovo“, the Sridivice Pasture Restoration Pilot Project Pilot (2015), funded by the European Union and led by prof. dr. sc. Jozo Franjić, grazing traditionally represented a complex, yet important process. Sub-chapter 1.1. of this Study „The impact of grazing onthe formation of vegetation in Biokovo“, describes the way pastures were managed in Biokovo in the past, which we cite as a good example for the Sub-Mediterranean area of the mountainous part of our country, whose examination would be of great benefit to our conditions too. It is stated that livestock farmers used to move out their livestock from their villages during the warmer period of the year. Around their houses they had farm outbildings that included stables for keeping animals during the colder part of the year. Here, livestock would intensively graze in a wide and narrow belt around houses, outside the „ban area“, all the way to the forest edge. In the spring, as temperatures began to rise, they moved livestock to higher altitudes, into the mountains, searching for suitable grazing areas. Together with livestock, they would stay there for several months, living in the stone cottages or stables specially built for this purpose, commonly known as catuns, with fenced pens for livestock.

During the hottest days in summer they would move even higher, under the mountain tips and passes and let livestock graze, until temperatures started to drop again and grazing became unproductive. In the late autumn and before the cold period of the year, they would again descend to the lower regions, closer to their villages and finally to the villages where they would stay during the winter. In this way the pastures were distributed in three storeys or zones. Apart from the search for good grazing areas, shepherds moved their livestock to the hills to fertilize the so-called vales in which potato or cereals such as barly and rye, and less frequently wheat and maize, would be grown next year. The Study further states that grass vegetation was mowed in late June and early July, after which livestock would be allowed to graze. After the rainfall, the so-called second-growth vegetation would restore providing food to animals that in return fertilize the area; this made pastures more abundant, and the quality of grass vegetation improved.

The importance of goats and the controversy of banning goat farming after World War II is still discussed and debated today. The most common opinion is that it was a very harmful decision of that time authorities, both from the socio-economic and the sustainability of biodiversity aspects, particularly concerning the pasture areas prone to forest succession. Their role was useful and served for maintaining the balance and biodiversity of the pastures, as they were cropping shrubs and young forest trees, thinning them and thus allowing more sunlight to penetrate, which is crucial for grass vegetation. In addition to soil and moisture, light is the most important factor in the quality assemblage of pasture and grassland areas. Exposure plays a special role, with particular reference to northern and northeastern positions where the thermal regime and insolation are less favorable.

The appearance of these areas is especially reflected in the last forty years, and especially since the 90s of the last century and after the war, with the number of livestock in the pastures of the hilly-mountainous area decreasing dramatically. In the area of karst, the so-called „rocky oases“ relatively rich in plant species have formed. However, shading caused by the spread of shrubbery and young degraded forests, the presence of invasive plants in the form of monocultures, and the absence of many pasture and meadow grasses and medicinal herbs, are some of the common occurrences in these micro-locations.

This is particularly pointed out by beekeepers, stating that despite the apparent abundance of biomass, such areas do not seem to provide for successful apiculture or honey yields.

Special attention should be paid to this problem as part of rural development and diversity programs, as former areas of rocky pastures are becoming more endangered and slowly but surely disappearing under the influence of the succession of woody vegetation. Therefore, habitats of rocky pastures, within the NATURA 2000 network, have been identified as nature conservation areas (Franjić *et al*., 2015). Apart from being very important habitats due to many species of plants, insects, small mammals and birds, they also contain many specialized species, such as butterflies, which can only survive in dry conditions with a lot of light (Ljubičić, 2012 cited by Franjić *et al*. 2015).

Pasture restoration

In view of the foregoing, and from the standpoint of understanding the ecological processes that accompany changes in the management of pastures, measures must be taken to reduce, mitigate or prevent the long-term effects on the status of this ecosystem.

The restoration interventions in habitats, biocenoses, and ecosystems should be based on knowledge of the causes of spontaneous vegetation succession processes (Krstonošić, 2013 cited by Franjić *et al*., 2015) after population abandonment and reduced grazing. Knowledge of the natural mechanisms of ecosystem recovery is of particular importance (Bartha *et al*., 2004 cited by Franjić *et al.*, 2015). Mediterranean rocky pastures, in particular, are secondary anthropogenic biotopes that have been shaped by grazing over the centuries. Therefore, grazing is the key factor affecting their appearance and structure, as well as habitats of some species. The productivity, structure, and floral composition of pasture is influenced by livestock species, grazing intensity, grazing duration, and the time of year when grazing takes place. In addition, the floral composition also influenced to a greater or lesser extent by environmental factors. The impact of livestock species on the productivity and floristic composition of pastures is manifested through the livestock's preferences in terms of plant species they consume, the way of grazing (biting) and trampling (livestock weight). Generally, livestock prefers to feed on young plants, starting with leaves, flowers and then stalks.

Cattle have the most beneficial impact on pasture, as they do not bite off the plants all the way down to the soil, but leave some ground-level leaves, which allows for faster regeneration. Horses bite lower and often uproot entire plants if they are to their liking, which has a particularly negative effect on the structure of the pasture. However, if horses are present in smaller numbers alongside cattle, they have a positive effect on evenly grazing and slowing down succession, as they graze areas that are not grazed by cattle, such as places with dung and plant species that are avoided by cattle.

Sheep are the most effective in terms of utilizing pastures, but they are also the fastest in causing severe degradation. They bite off the plants near the root (and often uproot them), they graze in large flocks, and make an extremely negative selection of plants, leaving behind a number of less edible species. Unlike sheep, goats can get up on their hind legs and crop shrubbery and trees, which can be very useful in slowing down succession (Šoštarić, Pisačić and Kovačević 1968; Ljubičić 2012; Ljubičić *et al*. 2014 cited by Franjić *et al.*, 2015). Succession in pastures leads to a decrease in the number of plant species, which further leads to a decrease in diversity, and ultimately the appearance of the landscape.

According to CORINE data in the period 2000 – 2018, there was a change in land coverage categories in Bosnia and Herzegovina, involving an area of 71,957 hectares (Ljuša and Čustović, 2019). The transition of land cover from one category to another also implies a change in the appearance of landscapes, which is influenced by various factors, including the anthropogenic factor being the most important one in terms of covering and altering the space by building infrastructure facilities, factories, reservoirs, by opening mines to exploit mineral resources, and by building settlements.

The abandonment of rural areas by the population and livestock has a huge impact on the succession process whereby agricultural land, especially pastures, gradually transition into coppices, shrubbery, degraded forest, and ultimately forest, leading to a complete loss of the anthropogenic appearance of the landscape we traditionally know and in which a sustainable balance of ecosystems was established at the local level. The change in the coverage and appearance of the areas at higher altitudes is a result of the abandonment of the rural area and its surrendering to invasive plant species in the direction of establishing a monoculture, which is especially the case in pastures and farm gardens.

Agricultural production in the mountainous region is very extensive. The predominant category is forestland whose use value ranges from VI to VIII category, with meadows and pastures on clearings and plateaus. When it comes to crops, potato, rye, oat, barley, etc., are grown in small isolated areas. Rockeries, lithosols, and other very shallow and infertile soils are classified as VIII category of use value. On the other hand, land situation at lower altitudes is considerably altered as a result of pressure from a large population that is constantly migrating from rural to urban and suburban areas, thus creating a requirement for the construction of massive infrastructure facilities, housing, and business buildings, etc.

In the high karst area, special attention should be paid to the problem of erosion through the implementation of good agricultural practices in land regulation, rational use of forest resources, proper organization of grazing and improvement of pasture conditions, as well as through taking the necessary fire control preventive measures and practices. It is also necessary to plan the extension of protected areas with different levels of protection depending on the degree of vulnerability to degradation, being a consequence of climate change and human activities (Čustović *et al.*, 2015).

5 CASE STUDIES FROM BOSNIA AND HERZEGOVINA AND THE WOCAT DATABASE

For the sake of illustration, this chapter provides summaries of interesting SLM technologies from Bosnia and Herzegovina that are implemented in practice and registered with the WOCAT database, as well as some interesting European SLM technologies from the WOCAT database that could be easily implemented in Bosnia and Herzegovina as well.

It should be noted that during the implementation of the project, especially in Tuzla Canton, several other practices, which according to their nature and objectives can be classified into sustainable land management practices, were identified and rather well documented (e.g. the so-called fishbone technique for erosion and surface landslide control in Banovići, contour tillage on slightly sloped land in Srebrenik). Interesting and useful land management practices that can be characterized and promoted as sustainable land management measures, can certainly be found in some other places in Bosnia and Herzegovina as well. Through field research and collaboration of land users and experts from local communities and research institutions, these practices should be described and documented, and their potential for the incorporation into sustainable land management technologies should be assessed. In line with the WOCAT approach, such practices should be documented and an effort should be made to inform as many land users as possible, as well as policy and decision-makers regarding the sustainable management of land and other natural resources.

The general idea is scaling out good practices to as many land users as possible and mainstreaming SLM technologies and approaches from practice into policies, programming, strategic and development documents, including the programming of material and financial support for land users who mitigate or prevent the effects of soil degradation by implementing SLM technologies.

5.1. Sustainable Land Management Technologies In Bosnia And Herzegovina Documented In The WOCAT Database

The WOCAT database includes three technologies from Bosnia and Herzegovina, two of which are from the Federation of Bosnia and Herzegovina, prepared as part of the implementation of the FAO/GEF project.

The technologies were researched and harmonized through the joint effort of expert associates from municipal agricultural services, land users and University of Sarajevo staff in 2018, and documented and accepted in the WOCAT database in early 2019. These two technologies were developed and implemented in the area of Tuzla Canton:

1. Stopping shallow landslides with timber piles,
2. Cultivation of blueberries on infertile or degraded soils using plant pots.

5.1.1. Stopping Shallow Landslides With Timber Piles (WOCAT No. 4285)

SLM technology - description

Application of timber pile structures formed in parallel aimed at stopping shallow and relatively small landslides. For better results, the technology can be combined with the installation of a drainage system.

Farmers in the northeastern parts of Bosnia and Herzegovina have traditionally applied this technology to remediate shallow landslides, surface erosion and loss of topsoil. The movement of the upper layers of soil occurs due to its unfavorable properties (shallow layer with relatively good surface permeability), and the fact that it rests (lies) on an impermeable geological substrate. In conditions of intensive or prolonged rainfall, the surface water reservoir becomes saturated, after which sub-surface flow is established on impermeable substrate thus causing internal erosion. After washing, the soil gradually begins to slide. This is especially the case when construction takes place on sloping terrains, with structures becoming an obstacle to the flow of sub-surface water or when the terrain is intersected mainly by roads, so that the soil loses support at the foot of the slope. In recent decades, this technology has been relatively frequently applied in the Municipality of Kladanj, whose agricultural and forestry services have provided a technical description and promoted the technology.

Landslides are one of the biggest problems in the hilly regions of Bosnia and Herzegovina and cause significant damage to agricultural land and housing facilities. Farmers apply this technology on their own farms, but it is also part of public interventions, such as protection of roads or other infrastructure against landslides, or during the reconstruction of roads damaged by landslides.

The purpose of the technology is to stop shallow (1.5 - 2-3 m deep) landslides of a relatively small area by preventing further movement of the soil. To our knowledge, the technology has so far been sporadically applied to approximately 20 - 30 sites in the Municipality of Kladanj. This relatively inexpensive technology can be funded by farmers, although a large number of such constructions were funded from the municipal budget.

FIGURE 43. *Installation of timber pile formation (Photo: Archives of the Municipality of Kladanj)*

The technology involves contour driving of timber piles in front of (below) the landslide front line. Land users recommend oak piles because of their high durability. Piles are usually 3.5 - 4 m long, with a diameter of 20 - 30 cm. One pile formation consists of two parallel rows of piles with spacing between rows of 1.5 - 2 m, and with similar spacing between piles in a row. The piles in rows are driven into the ground in such manner so that, when viewed from a bird's eye perspective, piles in adjacent rows form a zigzag pattern. Wooden laths interconnect the above-ground sections of installed piles.

FIGURE 44. *Connecting adjacent piles with wooden laths (Photo: Archives of the Municipality of Kladanj)*

One formation of piles is usually sufficient for the rehabilitation of smaller landslides, but for larger landslides, two formations, one below the other, are recommended. When repairing large landslides it is useful to combine the application of piles with the drainage of the terrain. If these large landslides are situated on steep slopes, it is recommended to strengthen the formation of piles with stone buttresses (retaining wall).

Classification of SLM technology

The goal of technology in relation to land degradation	Prevent land degradation Reduce land degradation
Land degradation to which technology relates	Soil erosion by water, sliding – Wm: Soil movement
SLM group	Stopping and restoring landslides Slope break
SLM measures included in technology	Structural measures - S3: walls, palisades, barriers

Technical specification and cost of SLM technology

Technical specification

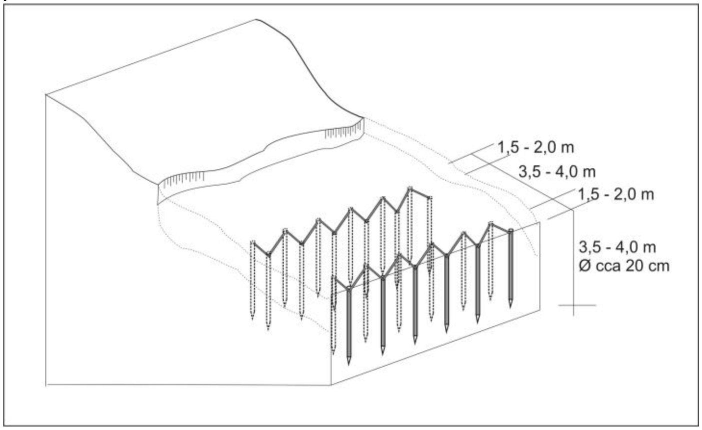

DIAGRAM 6. *Pile placement and configuration (Sketch: M. Bajrić, M. Blesić, 2018)*

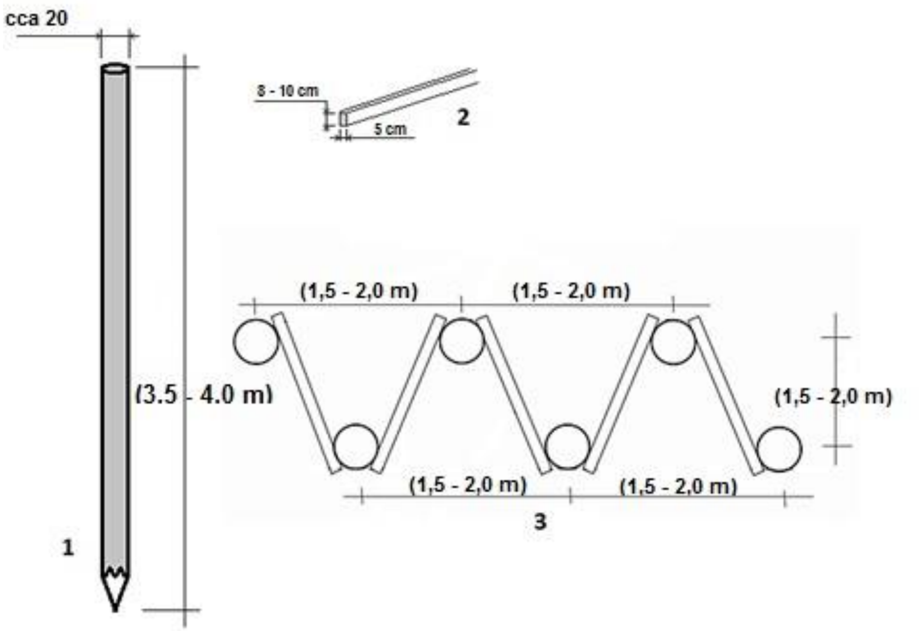

DIAGRAM 7. *Dimensions of piles (1), laths for connecting the piles (2) and the method of connecting piles in the adjacent rows (3) (Sketch: M. Bajrić, M. Blesić, 2018)*

Material	Timber piles, laths
Fieldwork	Field preparation according to technical design Driving piles into the ground and connecting them Optional: drainage of terrain and installation of stone buttresses
SLM technology implementation cost (calculation for a specific formation at the Borak site, on an area of 1,800 m^2)	3,940 EUR
SLM technology regular maintenance cost	-

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment								
Socio-economic	Farm income	Decreased						X		Increased
	Production diversity	Decreased					X			Increased
Ecological	Land loss	Increased							X	Decreased
Risks of climate change and natural disasters	Landslides	Increased							X	Decreased
Environmental impact	Downstream flooding	Increased					X			Decreased
	Downstream siltation	Increased					X			Decreased
	Damage to infrastructure	Increased							X	Decreased
	Damage to adjacent fields	Increased							X	Decreased

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative			X					Very positive
	Long-term	Very negative						X		Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative						X		Very positive
	Long-term	Very negative							X	Very positive

Advantages and disadvantages of SLM technology

Advantages of SLM technology	A relatively inexpensive way to stop and rehabilitate landslides Availability of structural material (timber)
Disadvantages of SLM technology	Technology alone, without additional investments (drainage), cannot solve the problem of large landslides Limited durability of timber piles

5.1.2. Cultivation Of Blueberries On Infertile Or Degraded Soils Using Plant Pots (WOCAT No. 4126)

SLM technology outline

Cultivation of blueberries in plant pots on infertile/degraded soils or soils with bad physical or chemical properties. The technology increases productivity and income. It requires a drip irrigation system.

The cultivation of blueberries in plant pots has been successfully implemented in the area of the Municipality of Živinice, on soils of poor physical properties and low fertility. Many efforts have been made to introduce a conventional production of blueberries, but without the expected results due to poor soil quality.

The predominant soil (Stagnoglay) in this area is poorly permeable to water, so even moderate rainfall causes the retention of water on the surface, making it difficult or completely impossible to cultivate the land. It is common knowledge that the successful cultivation of blueberries requires high acidity soils. Conventional planting of blueberries is often carried out on soils whose acidity is increased by various additives (often with wood sawdust or similar wooden materials). Practical experience has shown that over time the acidic properties of the soil in the zone of the development of the blueberry root change, i.e. soil/substrate acidity decreases due to resorption processes and neutralization of hydrogen ions by calcium in poorly permeable soils.

FIGURE 45. *Rows of blueberries in pots (Photo: M. Blesić, 2018)*

FIGURE 46. *Blueberry pot on the embankment (Foto: M. Blesić, 2018)*

Today's market offers multi-component substrates for the cultivation of blueberries, which, in addition to adequate acidity, have other properties necessary for good development of the blueberry's root system. Such substrates were also used in some localities of the Municipality of Živinice in conventional or modified conventional production (on embankments using primary soil and commercial substrates). The modification did not yield satisfactory results, probably because of the loss of substrate properties. It was only logical to conclude that a commercial substrate longer keeps its positive properties if its contact with the primary soil is reduced (e.g. by being placed in pots or bags).

The core quality of this technology lies in its ability to be applied to practically all soils of poor agricultural – productive properties, including heavily degraded soils. Though the cost of introducing the technology is relatively high, its maintenance is reduced to standard agro-technology in blueberry cultivation. In the Municipality of Živinice, technology is currently being applied only in the cultivation of blueberries. Previous results have shown that the cultivation of blueberries in plant pots provides a yield of about 15 t/ha, which is about 50% higher compared to the conventional cultivation. The farm on which the technology is described and documented cultivated blueberries of the Duke variety on 8 ha. The estimated life span and cost-effective exploitation period of blueberries grown in plant pots is about 15 years.

Regarding the technical characteristics, this technology implies planting two-year or preferably three-year-old blueberry seedlings into the plastic plant pots of 60 to 90 liters. The pots with blueberry plantings are placed in rows with a distance of 200 - 300 cm between rows, and 100 - 120 cm between the plant pots (from the center to center). The rows of plant pots are trussed with the original soil thus ensuring the physical stability of the plant pots and more favorable temperature and humidity conditions of the substrate and blueberry root in the pot. The technology requires possession and use of the drip irrigation system and fertigation.

The technology offers a relatively innovative way of establishing successful agricultural production on infertile or degraded soils. The initial positive experiences from the cultivation of blueberries in plant pots have resulted in the spread of technology in the area of Municipality of Živinice, which is, according to the scale of blueberry production, considered one of the leading blueberry producers in the Balkans.

FIGURE 47. *Irrigation of blueberries in plant pots (Photo: M. Blesić, 2018)*

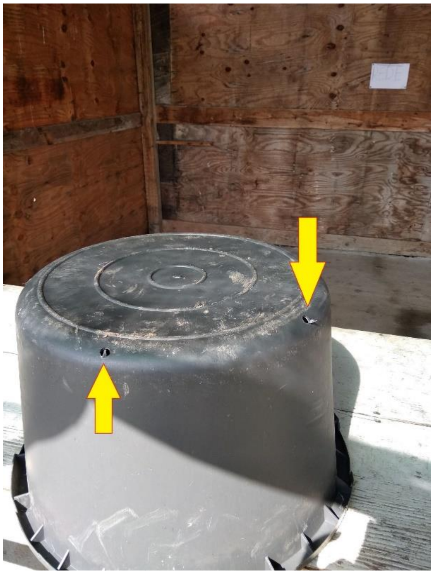

FIGURE 48. *Openings (holes) at the bottom of the pot (Photo: M. Blesić, 2018)*

Classification of SLM technology

The goal of technology in relation to land degradation	Improve agricultural production Prevent degradation and use of degraded land Increase the income of farmers
Land degradation to which technology relates	Physical degradation – Pc: compaction; Pk – crust formation; Pu – loss of bioproductive properties Chemical degradation – Cn: Decrease in soil fertility
SLM group	Management of sowing and planting
SLM measures included in technology	Vegetative measures – V1: Plant cover Management measures – M2: Change of management/intensity level

Technical specification and cost of SLM technology

Technical specification

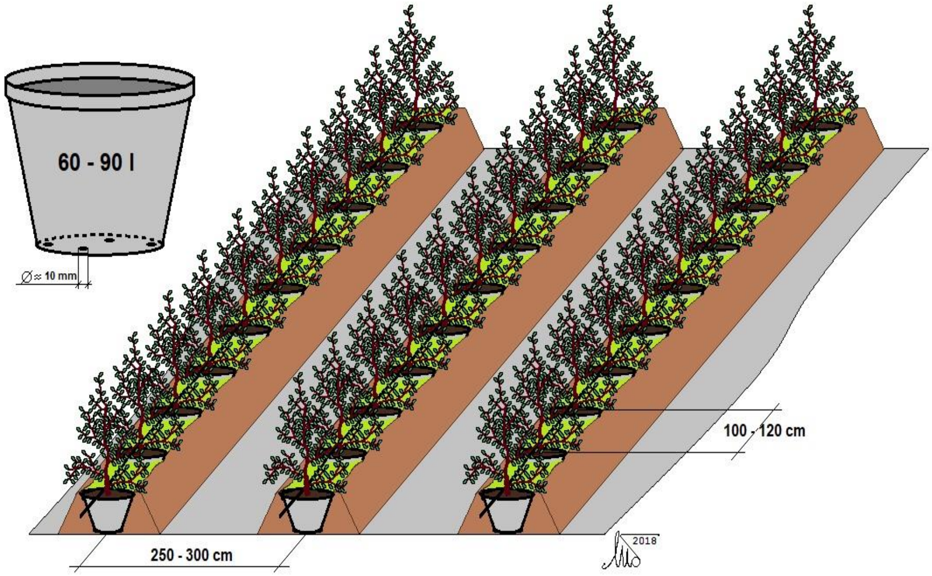

DIAGRAM 8. *Depiction of the container (plastic plant pot) and established blueberry plantation (Sketch: M. Blesić, 2018)*

Material	Blueberry plantings; substrate; plastic containers; drip irrigation system
Fieldwork	Preparation of the terrain (as required) Forming the rows of containers with the required spacing between rows and containers Filling the containers with substrate and planting of blueberries Forming the embankments by trussing the primary soil around containers Installing a drip irrigation system
Cost of introducing the SLM technology (calculation for 1 ha)	51,140 EUR
The maintenance cost of the SLM technology (including agrotechnical measures and fruit harvesting; annually, calculated for 1 ha)	18,700 EUR

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment								
Socio-economic	Crop production	Decreased							X	Increased
	Crop quality	Decreased						X		Increased
	Demand for irrigation water	Increased		X						Decreased
	Cost of agricultural inputs	Increased	X							Decreased
	Farm income	Decreased							X	Increased
Socio-cultural	Knowledge about SLM and degradation	Reduced						X		Increased
Ecological	Land coverage	Worsened							X	Improved
	Soil compaction	Increased					X			Decreased

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative		X						Very positive
	Long-term	Very negative							X	Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative						X		Very positive
	Long-term	Very negative							X	Very positive

Advantages and disadvantages of SLM technology

Advantages of SLM technology	Possibility for organizing agricultural production on infertile or degraded soils Much more profitable agricultural production Decreased workload compared to the conventional production of blueberries
Disadvantages of SLM technology	Relatively high cost of the introduction of technology (cost-effective in growing highly-priced crops) Necessity of a drip irrigation system Relatively short period of the exploitation of blueberries grown in containers

5.1.2.1. Economic Valorization Of Growing Blueberries In Plant Pots On Infertile Or Degraded Soils (Municipality of Živinice)

According to the WOCAT approach, cultivation of blueberries in plant pots on infertile or degraded soils has been evaluated as a technology with significant, highly positive socio-economic and environmental impacts, as well as with markedly positive impact on the ability to respond to droughts, floods, and other natural disasters. The benefits in relation to investment and maintenance costs over the long term were assessed as very positive. Only the short-term benefit in relation to investment is very negative stemming from the fact this technology implies significant initial investments, which is, under the current economic position of landowners and the current situation on the capital market and the absence of adequate incentive measures in the agricultural policy, a serious obstacle to its massive introduction into practice.

Cultivation of blueberries in plant pots on infertile or degraded soils on the studied farm takes place on an area totaling eight hectares, half of which is fully matured. The yields provided by mature plants amounted to 15 t per hectare, and all produced fruit was exported to the EU markets at the selling price of 8 KM/kg (about 4 EUR). The following tables provide a specification of the costs associated with the introduction of the technology (investment) and the annual cost of maintaining the technology per hectare, based on data obtained from the landowner applying the technology and the input supplier[36].

[36] Cost of inputs based on the prices in March 2019

TABLE 15. *Amount and structure of investment in establishing cultivation of blueberries in plant pots on infertile soil in the area of Živinice (EUR)*

Type of Cost	Unit measure	Quantity	Cost per Unit	Total	Share (%)
Blueberry plantings in containers	piece	2,800	4.68	13,100.56	25.30
Filling the containers with substrate and planting of blueberries	daily wage	28	26.02	728.50	1.41
Placing the containers and formation of rows	daily wage	30	26.02	780.54	1.51
Machinery for leveling the ground (optional)	hour	4	62.44	249.77	0.48
Other					
Plastic containers (65 l)	piece	2,800	4.87	13,623.58	26.31
Multifunctional substrate	l	182,000	0.06	11,332.23	21.88
Drip irrigation system with pump and water tank	ha	1	11,972.67	11,972.67	23.12
Total investment (per 1 ha)				**51,787.85**	**100.00**
Investment maintenance *					
Multifunctional substrate	l	182,000	0.06	11,332.23	
Replacement of substrate	Daily wages	28	26.02	728.50	

**In order to ensure high yields throughout the life span of the plantation, which is 15 years, it is necessary to replace the multifunctional substrate in the eighth year. In addition to the substrate itself, this activity also requires labor. This cost, by its nature, is investment maintenance, and is therefore listed in the table under the investment, but is not calculated within the investment; it is stated in the year of its incurrence (eighth year).*

Containers, plantings, substrate and irrigation system have a dominant share in the investment structure, while human labor accounts for only about 3%.

TABLE 16. *Amount and structure of annual maintenance cost in the cultivation of blueberries in plant pots on infertile soil in the area of Živinice (EUR)*

Type of Cost	Unit measure	Quantity	Cost per Unit	Total	Share (%)
Checking and maintenance of rows	daily wage	10	26.017	260.18	1.37
Maintenance of a drip irrigation system	ha	1	306.06	306.06	1.62
Maintenance of blueberry orchards (total)[37]	ha	1	18,363.35	18,363.35	97.01
Total maintenance			**18,929.59**	**100.00**	
Maintenance in the 8th year			**30,990.32**[38]		

A quantitative analysis of economic feasibility, i.e. profitability of the investment, which does not include other non-financial benefits of this technology, was made using the internal rate of return – one of the most commonly used methods for this analysis. Annual revenues were calculated based on a 15 t yield and the selling price of 8 KM (4.09 EUR). Considering that two-year-old plantings were used to establish plantations, no revenue was calculated in the first two years after the investment, and in the third year, it was calculated based on 60% of full yield.

Due to production and production-related market risks, the long-term nature of the investment, and the fact that the cost data were collected by users thus allowing for the possibility that some estimates were not sufficiently accurate, the profit was discounted at the rate of 10% when calculating the internal rate of return, which is significantly higher than the current cost of capital in Bosnia and Herzegovina. Even so, the internal rate of return was as much as 27%, which makes it highly profitable.

[37] Total amount estimated by technology users, including the cost of harvesting and packing

[38] Regular maintenance cost plus investment cost

However, it must be noted that this was a sufficiently big farm (8 ha) where it was possible to achieve levels of production that can provide sufficient quantities to place on the demanding EU market and achieve a high selling price.

Considering the many other benefits this technology brings to owners and other stakeholders, its spreading in practice would have numerous and manifold benefits, but a serious limitation is posed by the level of initial investment, the biological character of fruit production which implies delayed (subsequent) revenue generation, therefore the application of technology is not suitable for poor owners who, for some reason, have no access to loans.

TABLE 17. *Economic flow and internal rate of return on investment in establishing cultivation of blueberries in containers on infertile soil in the Municipality of Živinice (EUR)*

Year	Investment	Revenues	Costs	Profit[39]
0	**51,787.85**			
1		0	18,929.59	-18,929.59
2		0	18,929.59	-18,929.59
3		36,810	18,929.59	17,880.41
4		61,350	18,929.59	42,420.41
5		61,350	18,929.59	42,420.41
6		61,350	18,929.59	42,420.41
7		61,350	18,929.59	42,420.41
8		61,350	30,990.32	30,359.68
9		61,350	18,929.59	42,420.41
10		61,350	18,929.59	42,420.41
11		61,350	18,929.59	42,420.41
12		61,350	18,929.59	42,420.41
13		61,350	18,929.59	42,420.41
14		61,350	18,929.59	42,420.41
15		61,350	18,929.59	42,420.41
		IRR (Internal rate of return on investment)		

[39] IRR calculated using the discount factor for a 10% interest rate

5.2. Examples Of The Sustainable Land Management Technologies Used In Practice In Bosnia And Herzegovina

5.2.1. Contour Tillage (Municipality of Srebrenik)

SLM technology outline

Contour tillage – reducing or preventing soil erosion by water

Contour tillage is one of the commonly known and most widely used approaches to tilling sloped land. The approach itself is certainly one of the cheapest ways of reducing or preventing the removal of surface soil layer on sloped cultivated land by water. It is interesting that the contour soil tillage on mildly sloped terrains was much more widespread in our country prior to the mass introduction of mechanized (tractor) soil cultivation. A common reason for abandoning contour tillage by tractors is the risk of tipping over when moving and tilling on slopes. It is true that contour tillage cannot be performed on the slopes with high gradients, so much more expensive terracing of land is imposed as a solution to prevent water-erosive processes.

The purpose of the technology is, primarily, to prevent or reduce the loss of surface layers of soil due to runoff on slopes. The soil loss caused by water significantly increases with the downslope or upslope orientation of the cultivation. In addition to reducing the soil loss, contour farming also contributes to reducing the loss rate of rainfall water from the soil, which may be of particular importance in the areas with prolonged drought periods.

IMAGE 10[40]. *Contour tillage*

[40] Modified picture downloaded from: http://www.fao.org/tc/exact/sustainable-agriculture-platform-pilot-website/en

Contour tillage on slopes with gradient up to 5% is easy and, with good access and organization, does not consume much more time or energy compared to up- and down-slope tillage. On very gentle slopes, contour tillage when planting crops in rows can refer only to directing tillage and crop rows in parallel with isohypses, i.e. perpendicularly to the slope direction. On steeper terrains, contour tillage involves segmenting the slope by forming contour-bounded areas of banks, terraces or trenches, depending on the slope of the area (polygons) to be tilled. The formation of canals and banks is required here, and the terrain itself, after the formation of contour-bound polygons, resembles terraced terrain. When deciding on contour tillage with terracing, a number of limitations and conditions should be taken into account – the type of soil, maximum possible width of terraces on the slope, required height of cuttings and depth of canals, canal drainage direction, the intensity and frequency of extremely high rainfall.

The technology presented here refers to the elemental contour tillage on mildly sloped terrains, without the formation of contour-bounded polygons and terraces, and only with proper (contour) directing of tillage machines and direction of sowing, when it comes to crops. Skilled agricultural machine operators can form gentle banks and cuttings (furrowed terraces) to enhance the effects of technology. The introduction of technology does not require significant investments, only its adaptation to the specific conditions in the field. It is recommended that markers (geodetic surveying of the plots) for setting the direction of tillage with agricultural machines to be placed.

Classification of SLM technology

The goal of technology in relation to land degradation	Prevent or reduce land degradation
Land degradation to which technology relates	Soil erosion by water – Wt: Uniform loss of surface soil – surface erosion
SLM group	Measures to mitigate and cut the slope Diversion of water
SLM measures included in technology	Agronomic measures – A3: Soil surface treatment; Vegetation cover; A6: Other Management measures – M1: Change of land use type; M2: Change of management/intensity level

Technical specification of SLM technologies

Technical specification

 

FIGURE 49. and FIGURE 50. *The beginning of contour tilling at the locality of Sladna, Municipality of Srebrenik (Photo: H. Čustović, 2018)*

Material	Agricultural machinery for soil cultivation – turner plow
Fieldwork	Determining the slope of the land, direction(s) of the slope and drawing lines that fully or at least approximately follow the isohypses. Determining isohypses should be preferably done using appropriate instruments. In the field, contours are usually indicated by markers (stakes, etc.). Tillage is performed by moving agricultural machines in parallel with marked isohypses.

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment								
Socio-economic	Crop production	Decreased						X		Increased
	Farm income	Decreased					X			Increased
	Knowledge about SLM and land degradation	Decreased					X			Increased
Ecological	Soil losses	Increased						X		Decreased
	Soil fertility	Decreased						X		Increased
Environmental impacts	Flooding at the base of the slope	Increased					X			Decreased
	Soil deposits at the base of the slope	Increased						X		Decreased
	Contamination of surface water	Increased						X		Decreased

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative					X			Very positive
	Long-term	Very negative						X		Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative					X			Very positive
	Long-term	Very negative						X		Very positive

Advantages and disadvantages of the SLM technology

Advantages of SLM technology	Reduced soil loss from water erosion Prolonged retention of rainfall in the soil (better conservation) Increased production of (primarily) crops Practically no additional investment in the introduction and maintenance
Disadvantages of SLM technology	Need for more skilled (trained) operators of agricultural machinery (tractors)

5.2.2. Landslide Treatment Using The „Herringbone“ Drain Technique (Municipality of Banovići)

SLM technology outline

In most of Bosnia and Herzegovina, landslides occur as one of the most pronounced problems, not only in terms of degradation of agricultural land but also as a relatively common threat to housing and infrastructure. Landslides are triggered during periods of heavy rainfall or sudden snowmelt, often with dramatic consequences that sometimes require the evacuation of the population and temporary or permanent abandonment of the former residence. Although landslide prevention measures should be applied to all suspected terrains and wherever possible, landslide remediation measures are also required. Remediation of large landslides that have endangered housing, economic or infrastructural facilities is a major, costly and complex construction effort. Landslides that have damaged or endangered facilities and infrastructure generally get remedied, with less or more funding difficulties, whereas landslides that have led to the degradation of agricultural land are, unfortunately, still rarely remedied. Many landslides on agricultural land are not even reported, while the issue of degradation of agricultural and forest land by landslides, is only occasionally mentioned regardless of its constant presence.

FIGURE 51. *Emerging landslide at the site Omazići - Husanovići, Municipality of Banovići (Photo: M. Blesić, 2018)*

In recent decades, drainage mitigation or landslide stoppage using the „herringbone“ technique has been successfully applied in the area of the Municipality of Banovići. This procedure has proven to be successful in the territory of the Municipality, both in the rehabilitation of cost and construction-wise large landslides endangering residential buildings and infrastructure (even a cemetery in one case), and the rehabilitation of small-scale landslides threatening the agricultural land this municipality already lacks. It should be noted that slope drainage using the „herringbone“ technique has also proven to be successful in preventing the occurrence of larger landslides when the risk of the landslide was timely recognized and the treatment timely executed. Previous experience in the application of this technique in Banovići suggests its promotion and scaling-out as a relatively inexpensive sustainable land management technology.

The technology involves the design and construction of drainage canals in the field already affected by a landslide or in the field with signs indicating the possibility of landslides. In most cases, along the basic slope of the landslide, a central drain (channel) is formed, to which lateral channels are connected at an angle greater than 45^o. The channel network (depth, length, the spacing between collector channels) should be designed according to the specific situation on the ground. When designing and constructing the central drainage channel, the account should be taken of its endpoint, i.e. of the possible significant amounts of water that the installed drainage system will discharge during heavy rainfall. Excavated drainage channels are fitted with drainage pipes (which is the more expensive option) or, more commonly, with crushed stone fractions (cheaper option and easier for implementation). If the stone is used as a drainage material, it is recommended that the drainage channel is filled with it up to half its depth, making sure that, in agricultural fields, there is a layer of soil left above this drainage system that is deep enough for unimpeded cultivation. After the drainage material is laid, the channels are backfilled with soil. It is recommended that during the excavation of the channels, the top humus layer of soil is separated and returned to its top position after the channels are backfilled. When the channels are backfilled, the land should be leveled. In addition to the demonstrated efficiency in rehabilitating small as well as large landslides, the landslide drainage „herringbone“ technique has another important advantage – the acceptable cost of the treatment.

For example, the estimated cost of the designed remediation of a 0.56 ha landslide using this technique and with stone as drainage material at the locality Omazići - Husanovići in the Municipality of Banovići is about 3,000 KM (1,530 EUR)[41].

In the absence of precisely elaborated technology, it is necessary to carry out the previous probing of the terrain on deep landslides (to design the depth of drainage channels). If the permeability of soil above the drainage channels is poor, i.e. if it permeates or retains water poorly, cross-drainage by means of a ripper or mole drain is necessary to restore the hydraulic effect and accelerate the process of percolation of the water into the drainage trench and thereby the drainage of excess water from the ground surface.

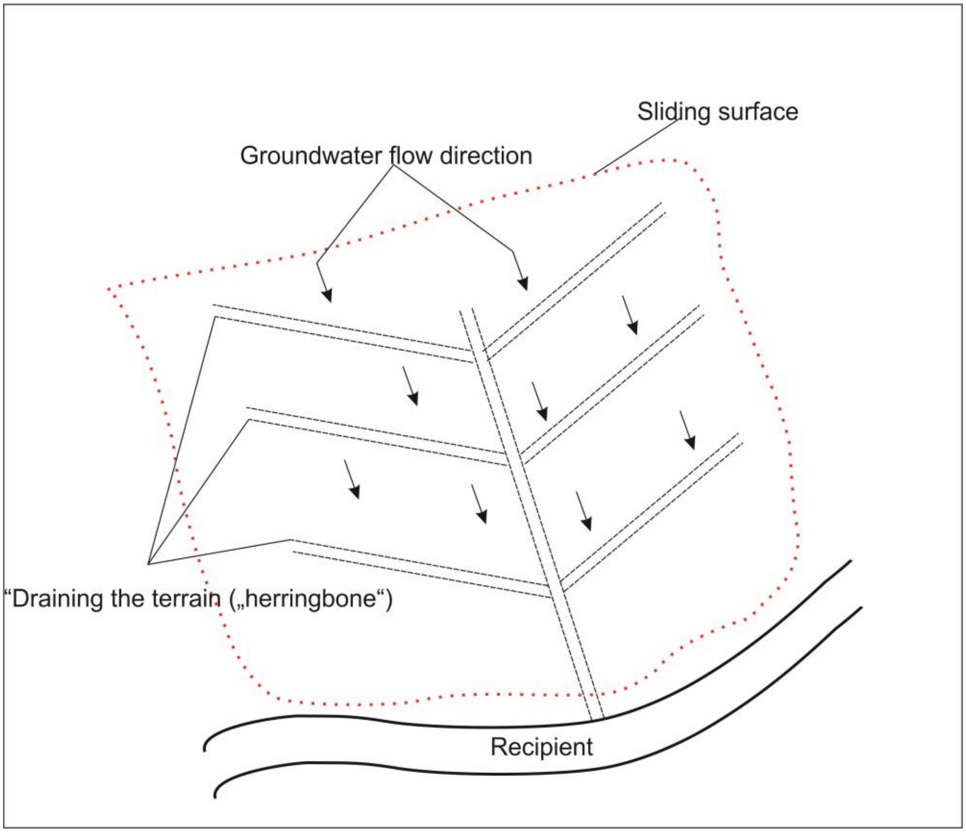

DIAGRAM 9. *„Herringbone" drain pattern (Sketch: M. Bajrić, 2019)*

[41] Selmet Husanović, Head of the Entrepreneurship Section of the Municipality of Banovići

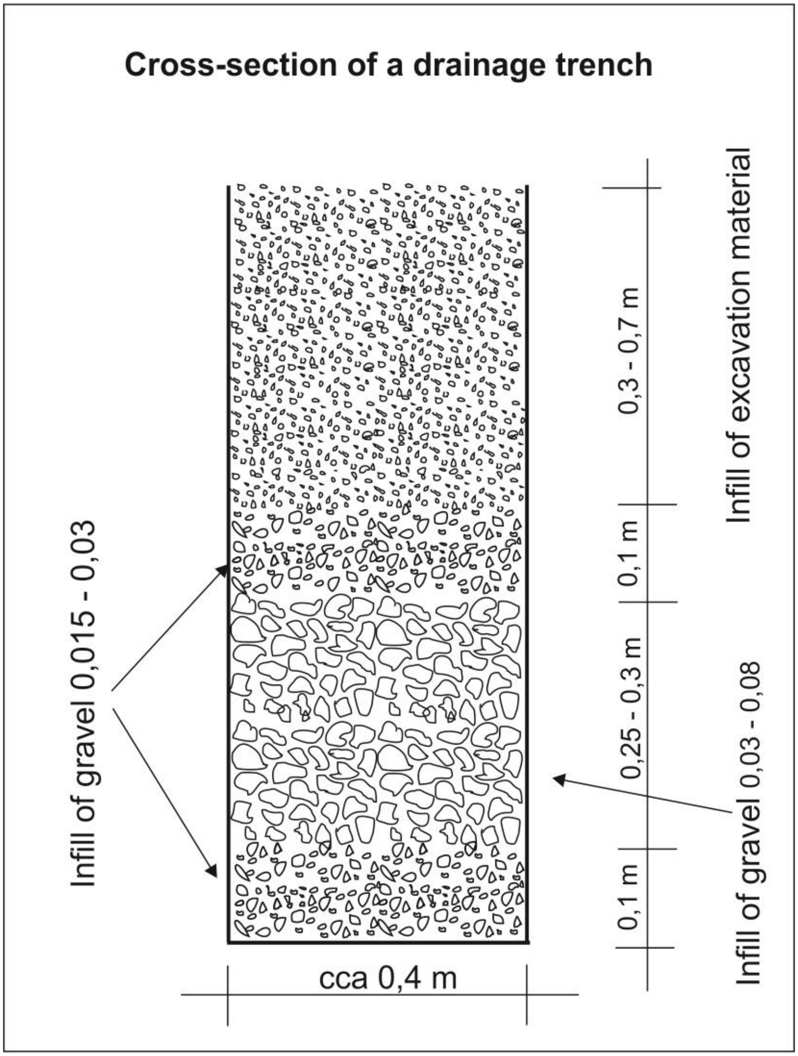

DIAGRAM 10. *Cross-section of a drainage trench filled with crushed stone fractions (Sketch: M. Bajrić, 2019)*

FIGURE 52. *Installation of the „herringbone“ drainage system in the area of Omazići - Husanovići (Photo: S. Husanović, 2019)*

5.3. Examples Of Some Of The Sustainable Land Management Technologies From European Countries Documented In The WOCAT Database

5.3.1. Converting Cropland To Grazing Land (Slovenia, WOCAT No. 2823)

SLM technology outline

The technology refers to the conversion of arable land to pastures on shallow skeletal soils with low yields or significant losses during prolonged dry periods.

The technology has been applied in the wider area of Ljubljana, with an average altitude of 350 m, and average annual precipitation of about 1,400 mm. The area is characterized by frequent stormy rains and occasional droughts during the growing season. The average annual precipitation is 1,400 mm. The soil is clayey-loamy, from medium-deep to deep, with a medium content of organic matter, and consequently with medium biodiversity and microbial activity. The soil is beyond the influence of secondary salinization and flooding. Farms are involved in commercial or mixed production, with less than 10% of revenues generated outside the farm. The average farm is well equipped with agricultural machinery. Farms are medium in size, with land either privately owned or leased.

FIGURE 53. *Comparative overview of pasture and arable land (Photo: M. Glavan, 2016)*

FIGURE 54. *Soil structure in pastures with a high percentage of skeleon (Photo: M. Glavan, 2016)*

Through technology, part of the area has been transformed into permanent grassland or pastures, whereby the grassland is established by sowing grass mixtures and fencing, i.e. protecting it from the presence of livestock in the initial stages of development. The pasture is organized through a rotational system of grazing dairy cows.

The purpose of this technology is to better utilize the natural potential of the soil, since it is relatively shallow and under tillage conditions, it has a relatively low moisture retention capacity. In this regard, permanent grasslands are a better solution, as they require less water and nutrients. Periods of drought have a considerably lower impact on the growth of grass compared to corn or other predominant crops. Additionally, grasslands increase the level of soil organic matter, sequester carbon, and thus contribute to reducing carbon emissions into the atmosphere and mitigate climate change. The main activities and costs of the introduction of technology are related to the sowing of grass mixtures and the procurement and installation of electric fences. Maintenance of the technology is reduced to the regular checks of the condition of electric fences and the removal of weeds at least once a year.

The advantages of the technology include soils being less exposed to the adverse effects of drought; increased content of soil organic matter; land users protected from losses associated with the abandonment of previous unproductive production. Additionally, this technology supports the growth of soil biodiversity and vegetation stands, improves animal wellbeing, and achieves increasingly high demand for meat produced from grazing livestock. Land users embrace this technology and find it useful, with only sporadic complaints on the loss of land for maize production.

Classification of SLM technology

The goal of technology in relation to land degradation	Prevent land degradation or reduce further land degradation
Land degradation to which technology relates	Chemical land degradation – Cn: Reduced soil fertility and soil organic matter Physical land degradation – Pc: Compaction, deterioration of soil structure due to frequent trampling and use of heavy machinery Biological land degradation – Bh: Loss of habitat: reduced plant biodiversity and increased fragmentation of habitat; Bq: Reduced biomass, reduced plant production; Bp: Increased incidence of disease and pest occurrences, reduced number of predators: reduced possibility of biological control of plant diseases and pests
SLM group	Pastures management
SLM measures included in technology	Management measures – M1: Change of land use

Technical specification and cost of SLM technology

Technical specification

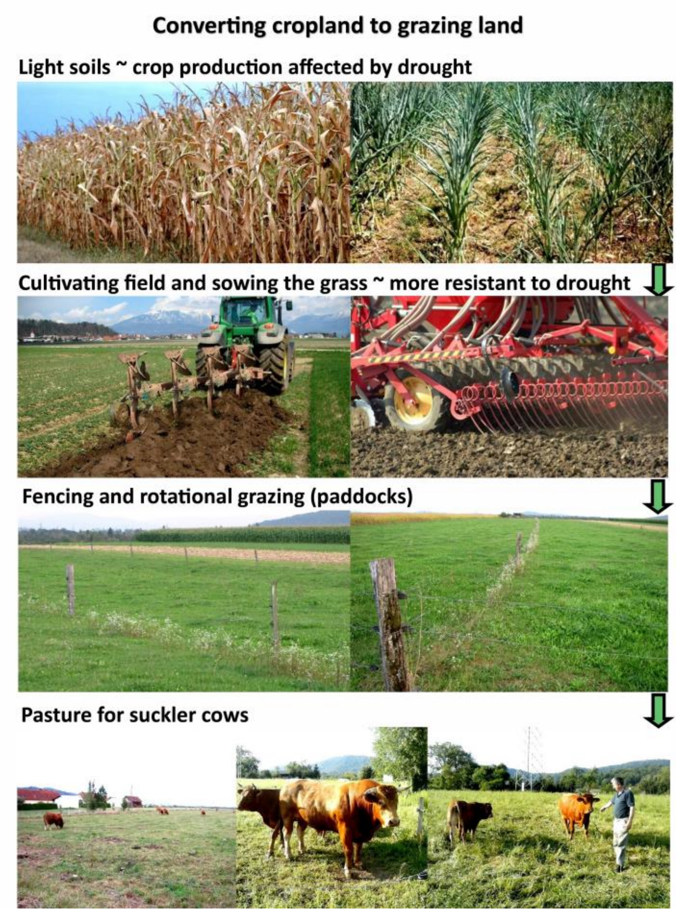

FIGURE 55. *Technical specification of the technology*

Material	Grass seed, electrical fence, inputs for soil tillage and preparation
Fieldwork	Preparation of soil (at the beginning of vegetation period) Grass sowing (possible during the vegetation period, prior to the installation of protective fences) Installation of the electric fence (winter, spring)
Cost of introducing the SLM technology	1,535.50 EUR
Maintenance cost of the SLM technology	70.00 EUR

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment									Comment
Socio-economic	Fodder production	Decreased						X		Increased	
	Fodder quality	Decreased						X		Increased	
	Land management	Hindered						X		Simplified	
	Expenses of inputs	Increased					X			Decreased	
	Farm income	Decreased					X			Increased	
	Diversity of income sources	Decreased					X			Increased	
	Workload	Increased				X				Decreased	Livestock requires constant monitoring
Ecological	Soil moisture	Decreased					X			Increased	
	Soil compaction	Increased				X				Decreased	No changes in light soils; on clayey soils compaction even increases
	Plant diversity	Decreased					X			Increased	
	Beneficial species	Decreased				X				Increased	
	Drought impacts	Increased					X			Decreased	
Off-site impacts	Groundwater/river pollution	Increased					X			Decreased	

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative						X		Very positive
	Long-term	Very negative						X		Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative						X		Very positive
	Long-term	Very negative						X		Very positive

Advantages and disadvantages of SLM technology

Advantages of SLM technology	Better use of land resources Adaptation to the increasingly frequent occurrence of drought Animal welfare; Landscape enhancement
Disadvantages of SLM technology	Transport of animals to pastures in spring In conditions of heavy clayey soils and with a lot of livestock grazing on pasture, soil compaction is increased (the number of grazing heads per unit area should be regulated)

5.3.2. Wooden Check Dams (Slovakia, WOCAT No. 1664)

SLM technology outline

Build small wooden dams in gullies, ravines or erosion canals to reduce the risk of torrential floods

The technology involves building wooden dams in gullies, erosion tributaries, or canals from which, during heavy rainfall, rapid water flows can cause torrential floods and removal of soil. The terrains on which the technology is implemented are on steep slopes with a relatively deep "V" profiles in the Carpathian foothills. The primary objective of the technology is to reduce the risk of local flooding usually caused by short-term heavy rainfall.

FIGURE 56. *Wooden dam during the dry summer period*

FIGURE 57. *Wooden dam during heavy rainfall*

Classification of SLM technology

The goal of technology in relation to land degradation	Reducing and halting negative processes in land degradation
Land degradation to which technology relates	Soil erosion by water – Wg: Gully erosion
SLM group	Management of water bodies (springs, rivers, lakes, seas)
SLM measures included in technology	Structural measures – S5: Dikes and dams, embankments and tree-lines along gullies and torrential streams

Technical specification and cost of SLM technology

Construction material	Rough round timber logs of 15 - 18 cm in diameter, and 100 - 500 cm long, timber piles whose length depends on the situation in the field
Fieldwork	Driving timber piles into the bed of torrential streams and forming a dam of timber logs. The dam height is up to 2 m. The capacity of the lake formed by a dam ranges from 20 m3 to 100 m3.
Cost of introducing the SLM technology	Oko 1,050 EUR*
Maintenance cost of the SLM technology	n/a

** Cost of establishing an average unit of SLM technology*

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment									Comment
Socio-economic	Damage to property	Increased						X		Decreased	Reduced damage to the property otherwise caused by flooding and silt deposits
Ecological	Water runoff rate	Increased						X		Decreased	Slowing down water runoff rate
Off-site impacts	Damage to public and private infrastructure	Increased						X		Decreased	

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative					X			Very positive
	Long-term	Very negative	X							Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative					X			Very positive
	Long-term	Very negative	X							Very positive

Advantages and disadvantages of SLM technology

Advantages of SLM technology	Easy to build and maintain Requires simple tools and equipment A small investment of labor to build
Disadvantages of SLM technology	Relatively short life span Requires maintenance Ineffective in extremely heavy rainfall that can result in damages and destruction of the dam (water-gate) After heavy rainfall, a large t quantity of sediments are deposited on the dam

5.3.3. Vegetated Buffer Strips (Italy, WOCAT No. 1646)

SLM technology outline

Plant buffer strips along the perimeter of agricultural land to prevent pollution of watercourses and reduce erosion

Buffer strips as a permanent vegetation cover are designed to prevent surface water pollution and minimize soil erosion. In the Veneto region, they are mainly formed along streams, canals, and pathways and may consist of grass, shrubs, and saplings, or a combination. Buffer strips that were once an integral part of agricultural landscapes have disappeared with the intensification of monocropping. In recent years, the reintroduction of buffer strips in the Venetian Plain (and throughout the Veneto region) has been supported as an agricultural and environmental practice for sustainable land management.

FIGURE 58. *A buffer strip of grass and trees formed along the canal bank (Photo: N. Dal Ferro, 2014)*

Vegetation buffer strips are a cost-effective and efficient way of improving the quality of surface waters which can be contaminated by pollutants from agricultural land. These strips also serve farmers to control soil erosion, sediment removal, stabilization of watercourse banks and reduce flood risk. Formation of permanent vegetation cover in strips contributes to habitat diversification and biodiversity improvement, and potentially diversification of farmers' income.

Vegetation buffer strips usually consist of shrubs or trees established in a formation of 1 - 2 m wide in combination with a grass strip of about 5 m wide. They have an optimal function in terms of reducing water pollution if formed along a watercourse.

Classification of SLM technology

The goal of technology in relation to land degradation	Prevent land degradation Reduce land degradation
Land degradation to which technology relates	Soil erosion by water – Wt: Uniform loss of the surface layer – surface erosion; Wr: Erosion on the banks of watercourses Biological degradation – Bh: Loss of habitat, reduced biodiversity and increased habitat fragmentation Water-related degradation – Hp: Reduced quality of surface waters: increased amount of sediments and pollutants in fresh surface waters due to soil pollution or other sources of pollution
SLM group	Improved land/vegetation cover; Management of water bodies (springs, rivers, lakes, seas); Windbreaks (protection belts)
SLM measures included in technology	Vegetation measures – V1: Cover consisting of trees, shrubs and grasses

Technical specification and cost of SLM technology

Technical specification

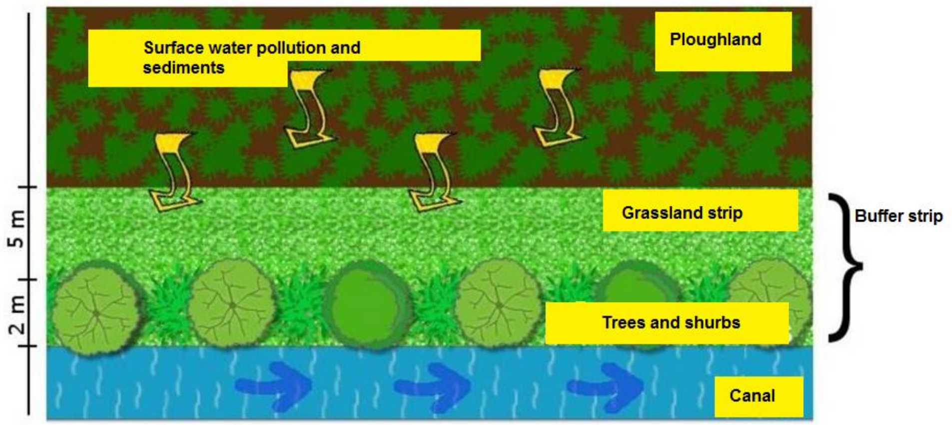

DIAGRAM 11. *Vegetation buffer strips*

Material	Grass seeds, shrub and tree seedlings
Fieldwork	Preparation, tillage and fertilization of soil in the strip area Sowing grass and planting trees and shrubs Installing an electric fence (winter, spring)
Cost of introducing the SLM technology	4,593.00 EUR
The maintenance cost of the SLM technology	254.00 EUR

Impacts of SLM technology

Type of impact	Character of impact	Impact assessment								
Socio-economic	Crop production	Decreased			X					Increased
	Wood production	Decreased							X	Increased
	Product diversity	Decreased					X			Increased
	Drinking water availability	Decreased						X		Increased
	Diversity of income sources	Decreased					X			Increased
Socio-cultural	Cultural opportunities	Decreased						X		Increased
	Recreational opportunities	Decreased						X		Increased
	Conflict mitigation	Decreased						X		Increased
Ecological	Water quality	Decreased						X		Increased
	Surface runoff	Increased							X	Decreased
	Soil cover	Decreased					X			Increased
	Soil loss	Increased							X	Decreased
	Nutrient cycling/ recharge	Decreased					X			Increased
	Biomass/ above ground C	Decreased						X		Increased
	Plant diversity	Decreased					X			Increased
	Habitat diversity	Decreased						X		Increased
Off-site impacts	Water availability	Decreased						X		Increased
	Downstream flooding	Increased						X		Decreased
	Groundwater/ river pollution	Increased						X		Decreased
	Buffering/ filtering capacity	Decreased							X	Increased
	Damage on neighbours' fields	Increased						X		Decreased

Assessment of the cost/effect ratio of SLM technology

	Term	Assessment								
Benefits in relation to the implementation cost	Short-term	Very negative			X					Very positive
	Long-term	Very negative						X		Very positive
Benefits in relation to the maintenance cost	Short-term	Very negative						X		Very positive
	Long-term	Very negative						X		Very positive

Advantages and disadvantages of SLM technology

Advantages of SLM technology	Protection of soil from erosion by water Protection of the quality of surface waters Improvement of the diversity of agro-ecological systems Diversification of agricultural production on farms Relatively low construction and maintenance cost in relation to positive environmental and production impacts
Disadvantages of SLM technology	It is sometimes difficult to reconcile crop production with established buffer strips The performance of buffer strips can be compromised by extreme weather conditions Low efficiency if there is no regular and long-term maintenance

ANNEXES 6

Annex 1. Overview Of SLM Technologies Documented In The WOCAT Database By European Countries (As Of Early July 2019)

Country	Name of SLM technology	Short description of SLM technology	Link
Belgium	**Non - inversion shallow cultivation**	Establishing plant cover in strips or banks, with only minimal shallow tillage allowed	https://qcat.wocat.net/en/wocat/technologies/view/technologies_966/
Belgium	**Non - inversion deep cultivation**	Establishing plant cover in strips with deep tillage allowed only by soil ripping (non-inversion)	https://qcat.wocat.net/en/wocat/technologies/view/technologies_967/
Bosnia and Herzegovina	**Cultivation of blueberries on infertile/degraded soils using plant pots**	Cultivation of blueberries in plant pots on soils with poor physical or chemical properties. Technology enhances productivity and increases income. Requires a drip-irrigation system.	https://qcat.wocat.net/en/wocat/technologies/view/technologies_4126/
Bosnia and Herzegovina	**Addressing shallow landslides by using wooden pole structures**	Application of timber pile parallel constructions aimed at preventing shallow and relatively small (in the area) landslides. For better results, technology can be combined with drainage systems.	https://qcat.wocat.net/en/wocat/technologies/view/technologies_4285/
Bosnia and Herzegovina	**Afforestation of bare land in karst areas**	Afforestation of barren land in Herzegovina, a vulnerable karst area, to increase water retention capacity and reduce land degradation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_4367/
Estonia	**Permanent grassland on peaty and eroded soils**	Permanent grass cover established to protect land from further erosion or decomposition of peatland	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3113/
Estonia	**No - tillage**	No-till farming or direct drilling as a way of growing crops or maintaining meadows without ploughing	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3089/

Country	Name of SLM technology	Short description of SLM technology	Link
Estonia	**Reduced tillage**	Reduced (minimum) tillage as a tilling method involving ploughing of 15 - 18 cm deep	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3120/
France	**Les prairies pharmacies**	Special seed mixtures for pastures. Maintaining and enhancing grassland productivity with improved health of animals	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3175/
France	**Pâturage amélioré par du Ray - grass et Trèfle Blanc**	Clover pastures	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3160/
France	**Restauration d'un bocage à l'aide de parcs éléctriques à brebis**	Strips of hedges or strips for planting shrubs or other useful plants protected from grazing animals by electrified fence	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1737/
France	**Les Betteraves dans l'alimentation du bétail**	Growing beets for animal feed	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3228/
France	**Rotation des cultures**	Crop rotation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3167/
France	**Non Labour**	No-till cultivation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3164/
France	**Construction en pierres sèches**	A combination of supply channels and dry stone walls in vineyards on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1124/
France	**Jardin avec cinq parcelles en rotation avec céréales, poules, racines, cochons et milpa**	Annual rotation of livestock and crop farming, 5-year cycle	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1763/
Greece	**Crop rotation for green manuring in greenhouse**	Rotation of crops (sorghum - tomato) for green fertilization in greenhouses	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1246/
Greece	**No tillage operations, plastic nets permanently on the soil surface**	Technology involves covering the surface of land that is not cultivated with plastic nets	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1087/

Country	Name of SLM technology	Short description of SLM technology	Link
Greece	**Grazing land afforestation with Ceratonia siliqua (carob trees) in the Mediterranean**	Afforestation of natural grazing land with carob trees	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1600/
Greece	**Rainwater harvesting for greenhouse irrigation**	Rainwater harvesting (from greenhouse roof) for greenhouse irrigation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1658/
Greece	**Soil erosion control by ridges**	Shaping the land in small ridges and using the interspace for cultivation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2922/
Greece	**Application of water by drip irrigation**	Drip irrigation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1456/
Greece	**Land terracing in olive groves**	Terraces on slopes to reduce water erosion and enable certain water conservation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1512/
Greece	**Water and soil conservation by using rock fragments**	Leaving rock fragments in/on the soil in order to reduce soil evaporation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2911/
Greece	**Transport of freshwater from local streams**	Transport of freshwater from local watercourses for irrigation purposes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1042/
Greece	**Olive groves under no - tillage operations**	Cultivation of olives under no tillage and no herbicide application conditions	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1035/
Greece	**Establishment of intensive grazing areas on low productive slopes**	Plowing and sowing, mostly oats or legumes in the fall, and grazing the growing plants in the spring	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2900/
Greece	**Application of biological agents to increase crop resistance to salinity**	Application of plants tolerant to increased salinity and additives to salinated soils aimed at improving their properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1281/
Greece	**Integrated water - harvesting and livestock water - point system**	Integration of a cement pan and collection well system for water harvesting serving as livestock water point	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1206/
Netherlands	**Humic acid application**	Adding humic acid to the soil aimed at supplying it with the organic matter without adding nitrogen and phosphorus	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1254/

Country	Name of SLM technology	Short description of SLM technology	Link
Netherlands	Intercropping of grass and corn to increase soil organic matter	Intercropping of grass and corn to increase soil organic matter	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1248/
Netherlands	Non - inversion shallow tillage on sandy soils in the Netherlands	Non-inversion tillage performed by special machines; applicable to the cultivation of any crops	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2958/
Netherlands	Organic agriculture with vegetable and arable crops on sandy soils	Certified organic production, with a rotation of arable and other crops	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2978/
Netherlands	Submerged drains	Drains installed in pastures or peatland to decrease soil degradation and emission of carbon dioxide and nitrogen monoxide, as well as to maintain groundwater level	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1704/
Netherlands	Manure separation to better distribute organic matter at farm level	Manure separation as a common practice in the Netherlands to improve nutrient use efficiency. The purpose of manure separation is to produce a thick fraction with high contents of organic matter and low moisture content. The thick fraction is a valuable fertilizer and can be transported over large distances.	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1256/
Netherlands	Organic agriculture with vegetable and arable crops on sandy loam soils	Certified organic agriculture, with a rotational combination of arable and vegetable crops on sandy loam soils in the Netherlands	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3305/
Netherlands	Increased organic matter input by using organic fertilizers (slurry and manure) instead of mineral fertilizers	Partial decrease in the application of mineral fertilizers thanks to increased application of manure	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2965/

Country	Name of SLM technology	Short description of SLM technology	Link
Netherlands	**Postpone grassland renewal**	Postponing the timing of ploughing a grassland field by one or two years aimed at retaining soil nutrients and organic matter	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1662/
Iceland	**Applying organic residuals on denuded areas**	Leaving organic residues on denuded soils	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1761/
Iceland	**Fertilizing and re - seeding degraded rangelands**	Restoration of degraded land with natural vegetation cover by adding small portions of mineral fertilizers and plant seeds	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1261/
Iceland	**Planting trees to establish local seed banks**	Afforestation with native species	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1672/
Italy	**Variable rate biosolids management**	Application of precision farming and variable rate application technology for optimization of organic amendments use	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1663/
Italy	**Wetland system**	Man-made water basins with vegetation cover to control diffuse pollution	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1647/
Italy	**Vegetated buffer strips**	Vegetated buffer strips in the margins of agricultural land to prevent pollution of watercourses and reduce erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1646/
Italy	**Agroforestry system**	Silvo-arable systems for production of annual crops on tree plots	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1230/
Italy	**Unvegetated strips to reduce fire expansion**	Unvegetated strips dividing a continuous forest into smaller patches to reduce spreading of wildfires	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1606/
Italy	**Pasture manuring (application of manure from shelter)**	Pasture manuring	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1209/
Italy	**Selective cutting**	Selective cutting of forest trees to prevent the risk of wildfires and their spreading	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1610/

Country	Name of SLM technology	Short description of SLM technology	Link
Italy	**Controlled grazing in deciduous woods as an alternative to grazing on rangeland**	Summertime grazing in deciduous forests when natural pastures suffer water stress	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1463/
Italy	**Root - oriented cover crops**	Crops with high root-growth capacity (or other underground parts) improve soil quality	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1291/
Italy	**Conservation agriculture**	Agricultural production and residue management under no-tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1225/
Italy	**Re - introduction of organic amendments in croplands**	Re-introduction of biosolids to improve fertility of mineral soils	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1280/
Italy	**Biochar application as a soil amendment**	Application of fine-grained biochar as an amendment to improve soil properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1279/
Italy	**Ploughing and seeding of fodder species to recover degraded grazing areas**	Ploughing and seeding of fodder species on degraded pastures prevents shrub encroachment of pastures	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1210/
Italy	**Vallerani Water Harvesting System**	Use of a special tractor-pulled plow to construct water-harvesting catchments	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1762/
Italy	**Green cover in orchards**	Perennial grasses in orchards and vineyards between rows to provide permanent soil cover	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1290/
Italy	**Crop rotation with legumes**	Crop rotation with legumes to improve soil fertility	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1227/
Italy	**Continuous soil cover on croplands**	Maintenance of continuous soil cover by alternating crops and cover crops to improve soil quality and reduce water pollution from agriculture	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1217/
Italy	**Cutting of Ferns in degraded pastures to use as litter and fodder**	Cutting of ferns to use as fodder and mitigate pasture degradation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1214/

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Italy	**Metallic fences to prevent damages to pastures from wild boars**	Metallic fences to prevent damages to pastures from wild bores	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1608/
Cyprus	**Agricultural terraces with dry - stone walls**	Dry-wall terraces on steep slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1702/
Cyprus	**Carob tree protection from rats**	Carob tree protection from rats, by using aluminum foils	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1703/
Cyprus	**Fodder provision to goats and sheep to reduce grazing pressure on natural vegetation**	Provision of fodder to goats and sheep to reduce grazing pressure on natural pastures and natural vegetation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1247/
Hungary	**Conventional (contour - line and ploughing) tillage**	Conventional contour tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1081/
Hungary	**Farmyard manuring**	Fertilization of agricultural land using mature farmyard manure	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3063/
Hungary	**Conservation tillage**	Non-inversion conservation tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1080/
Hungary	**Conservation tillage**	Conservation tillage with minimum soil disturbance	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3065/
Norway	**Reduced tillage**	Reduced tillage aimed at decreasing erosion by water and soil losses	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1245/
Norway	**Grass Covered Riparian Buffer Strips**	Grass covered riparian buffer strips along cropland waterways	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1656/
Germany	**Water retention polders without agriculture to improve water management**	Water retention polders without agriculture to facilitate water management and reduce risk from flooding	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1582/
Germany	**Adapted management of organic soils**	Re-wetting of organic soils and supporting measures on peatland, especially under increased grazing	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1697/

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Germany	**Grassland preservation**	Grassland preservation by the avoidance of ploughing and its transformation into cropland	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1699/
Germany	**Drainage of coastal areas in north - western Germany**	Draining of coastal area land reclaimed from the sea in north-western Germany	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1714/
Germany	**Water retention polders to improve water management**	Non-agricultural water retaining polders in the coastal areas to reduce flood risk	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1583/
Germany	**Water retention polders with adapted land use (North Sea region)**	Alternative production on polders	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1660/
Germany	**High - quality inner urban development**	A scenario simulation of land use change where high-quality inner urban development is promoted; it includes rehabilitation of brownfields, reuse of vacant lots, use of gaps between buildings and the improvement of existing structures	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1698/
Germany	**Mobile cultivation beds**	Mobile cultivation beds (open containers) for vegetable cultivation in urban areas	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1678/
Poland	**No - till**	No-till is a system where crops are planted into the soil without primary tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2851/
Poland	**Chicken manure in non irrigated arable land**	Chicken manure as organic fertilizer in non-irrigated arable land	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2848/
Poland	**Ex - post and ex - ante soil sealing maps**	*Ex - post* and *ex - ante* soil sealing maps	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1716/
Poland	**Organic agriculture in hop cultivation**	Organic hop cultivation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2852/
Portugal	**Minimum tillage in Mediterranean vineyards**	Minimum tillage in Mediterranean vineyards	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2879/
Portugal	**Post - fire salvage logging; post - fire traditional logging**	Traditional and almost complete removal of trees after fire (post-fire salvage logging).	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1713/

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Portugal	**Primary strip network system for fuel management**	Linear strips without vegetation cover are formed in areas where total or partial removal of the forest biomass is possible. The technology contributes to preventing the occurrence and spread of large forest fires and mitigating their consequences.	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1361/
Portugal	**Post - fire Natural Mulching**	In certain situations, the leaves from the burnt trees create a natural mulch that prevents or reduces soil erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1298/
Portugal	**Prescribed fire**	Use of controlled fire to prevent the likelihood of more damaging wildfires	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1534/
Portugal	**Post - fire Forest Residue Mulch**	Forest residue mulch is spread immediately after a wildfire in order to reduce soil erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1186/
Portugal	**Hydromulching for reducing runoff and soil erosion**	Hydromulching for preventing soil erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1299/
Romania	**Non - inversion tillage for arable land**	Soil tillage with a chisel, non-inversion of furrow	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2950/
Romania	**Direct drill (no - till) for arable cropping systems**	Direct drill – no till or any other soil cultivation operations	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2957/
Romania	**Cropping perennial grasses (Miscanthus sinensis gigantheus) on soils contaminated with heavy metals**	Cropping perennial grasses on soils contaminated with heavy metals and use as commercial energy crop	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1706/
Romania	**Leguminous crop cultivated in plot temporarely set outside the crop rotation**	Leguminous crops in crop rotation, most commonly with cereals	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2963/
Russian Federation	**Применение органо - минеральной системы удобрений**	Incorporation of organo-mineral fertilizers into the soil	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1310/

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Russian Federation	**Мелиорация (известкование), повышение плодородия серых лесных почв Владимирского ополья**	Increasing fertility of brown forest soils through the cultivation of annual crops and fertilization with organic and mineral fertilizers	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1262/
Russian Federation	**Minimum Tillage**	Minimum tillage with the use of special seeders	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1315/
Russian Federation	**No - till crop production**	No-till crop production, with direct drilling	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1288/
Russian Federation	**Создание плодового сада на территории университетского кампуса**	Planting an apple orchard on the university campus	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1674/
Russian Federation	**Мелиорация (известкование) серых лесных почв, повышение плодородия**	Increasing fertility of brown forest soils	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1249/
Russian Federation	**No Till**	Direct seeding under no-till	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1319/
Russian Federation	**Drip irrigation**	Drip irrigation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1371/
Slovakia	**Wooden check dams**	Small wooden check dams built in erosion rills, grooves or gorges to reduce flood risk	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1664/
Slovakia	**Level ditches in cropland**	Conservation measures for eroded cropland. The technology contains level ditches of various lengths, which are dug along a contour	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1666/
Slovakia	**Water retention basin, a flood - control reservoir**	Water retention basin, a flood control reservoir; a complex hydraulic facility	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1675/
Slovenia	**Converting cropland to grazing land**	Converting cropland to grazing land	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2823/
Slovenia	**Integrated soil fertility management with biochar and zeolite**	Adding biochar and zeolite to the soil to improve its fertility	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2785/

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Slovenia	**Organic agriculture**	Organic agriculture, based on a 5-year crop rotation cycle	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2795/
Slovenia	**Fertilising with farmyard manure**	Fertilizing with farmyard manure from dairy cows	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2824/
Serbia	**New patented technology of raising forest and orchards in the extremely unfavorable environmental conditions**	Complete mulching with plastic material, planting and cultivating forest and fruit trees on such prepared soil	https://qcat.wocat.net/en/wocat/technologies/view/technologies_500/
Spain	**Reduced contour tillage of cereals in semi - arid environments**	Reduced contour tillage of winter cereals on slopes in semi-arid conditions	https://qcat.wocat.net/en/wocat/technologies/view/technologies_939/
Spain	**Seedling**	A post-fire measure in areas prone to erosion; the objective is to quickly create vegetation cover	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1266/
Spain	**Cover crops on olive orchards**	Grass as a cover crop in olive orchards to reduce the risk from erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1173/
Spain	**Adición de enmiendas a suelos contaminados**	Adding mineral and organic substances to soils in order to improve their properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1273/
Spain	**Water harvesting from concentrated runoff for irrigation purposes**	Water harvesting from concentrated runoff for irrigation purposes in their proximity	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1517/
Spain	**Application of 'Preparation 500' in agricultural soils under a biodynamic management**	Application of "Preparation 500" (cow horn manure) in agricultural soils under a biodynamic management	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2690/
Spain	**Contour - felled log barriers**	Counter-erosion slope stabilization	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1681/
Spain	**Prescribed fire**	Prescribed burns or intentional ignition of grass and shrub cover in forests aimed at reducing the risk of large forest fires	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1679/
Spain	**Reforestation**	Re-forestation (post-fire) of forest stands on land that had recent tree cover	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1267/

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Spain	**Straw mulching to improve soil quality**	Application of straw mulch on bare soil in order to prevent soil erosion and improve soil properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1255/
Spain	**Multi - specific plantation of semiarid woody species on terraces with stone walls in ravines and gullies**	Plantation of semi-arid species on terraces with stone walls in ravines and gullies	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1649/
Spain	**Selective clearing and planting experiment to promote shrubland fire resilience**	Selective clearing of fire-prone shrubs and planting of more fire-resistant species and their spreading	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1579/
Spain	**Non tillage**	Conservation of soil on a slope without tillage, with keeping the plant residues of previous crops or adding plant residues from other areas	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1264/
Spain	**Cover crops in organic vineyard**	Use of cover crops in vineyards to reduce erosion risk and increase soil organic matter	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1162/
Spain	**Selective forest clearing to prevent large forest fires**	Selective forest clearing to prevent large forest fires	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1586/
Spain	**Ecological production of almonds and olives using green manure**	Ecological production of olives and almonds using green manure	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1019/
Spain	**Annual green manure with Phacelia tanacetifolia in southern Spain**	Green fertilization using *Phacelia tanacetifolia* in southern Spain	https://qcat.wocat.net/en/wocat/technologies/view/technologies_3219/
Spain	**Organic mulch under almond trees**	Organic mulching in almond orchards to prevent soil erosion by water and excessive water evaporation from the soil	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1109/
Spain	**Cleared strip network for fire prevention (firebreaks)**	Cleared strips in forests to prevent spreading of wildfires	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1592/
Spain	**Chipped branches**	Chipped branches application on the soil in order to prevent or reduce soil erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1269/

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Spain	**Catch crop**	Various catch crops and grass covers on bare soil between rows of the primary crop in order to prevent erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1268/
Spain	**Natural revegetation**	Creating conditions for a fast natural re-vegetation on areas affected by the fire	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1265/
Spain	**Multi - specific plantation of semiarid woody species on slopes**	Plantation of semi-arid woody species on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1618/
Spain	**Vegetated earth - banked terraces**	Earth-banked terraces in cereal and almond cropland covered with drought-resistant shrubs.	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1516/
Spain	**Reduced tillage of almonds and olives**	Reduced tillage of almonds and olives to improve physical and chemical soil properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1711/
Spain	**Organic amendment located in dripper point in organic citrus production**	Organic amendments located in dripper point in organic citrus production	https://qcat.wocat.net/en/wocat/technologies/view/technologies_2010/
Spain	**Aserpiado**	Aserpiado – a traditional method for creating micro-depressions, usually in vineyards, on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_907/
Spain	**Fitoestabilización de suelos contaminados**	Planting or sowing species for the immobilization of elements-soil contaminants	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1272/
Spain	**Afforestation with Pinus Halepensis after the fire of 1979 (La Molinera)**	Post-fire afforestation with *Pinus halpensis* to reduce erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1584/
Switzerland	**Dyker - System (oder Lochstern) im Kartoffelanbau**	Attached behind the potato planting machine, Dyker (Lochstern) digs channels at the bottom of a furrow	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1296/
Switzerland	**Maize strip tillage**	A tillage system for maize cultivation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1006/

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Switzerland	**Green cover in vineyards**	Naturally grown perennial grasses in vineyards	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1018/
Switzerland	**Vineyard with natural grass cover in an arid alpine zone**	Vineyards with natural grass cover in the arid alpine region	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1136/
Switzerland	**Hangunterteilung durch Ackersaum**	Slope subdivision using the Ackersaum system: alternating and contoured tilled and vegetated strips on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1680/
Switzerland	**Slope subdivision through a field seam**	Contoured grass strips on slopes to reduce erosion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1670/
Switzerland	**Direct seeding**	Direct seeding, no-till	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1007/
Switzerland	**Maize strip tillage**	A tillage system used for corn cultivation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1009/
Switzerland	**Terasses used for hay production and grazing**	Traditional terraces for hay production and grazing, and currently used for crop production as well	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1193/
Switzerland	**Dyker System**	The Dyker (Lochstern) system consists of a set of wheels with three to four inclined shovels each; it is attached to the rear end of the planting machine and digs holes in the bottom of the furrows between the potato banks	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1304/
Switzerland	**Maize strip tillage**	Tillage system in the cultivation of maize	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1008/
Switzerland	**Contour small bench terraces with permanent green cover in vineyards**	Narrow contour terraces with vegetation cover in vineyards on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1011/

Country	Name of SLM technology	Short description of SLM technology	Link
Switzerland	**Minimierung des Herbizideinsatzes**	Experiments and a high level of knowledge have shown that there are ways to reduce and optimize the use of herbicides in agriculture of Switzerland	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1271/
Switzerland	**Pflugloser Ackerbau im Biolandbau**	Organic agriculture without conventional ploughing, with the use of other machines and tools for minimum soil disturbance	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1284/
Switzerland	**Bodenschonende Landnutzung mit dem On – Land - Pflug**	In organic agriculture, plough-free farming is still difficult. In order to protect soil from compaction, farmers can apply ploughing that is shallower (10-15 cm) compared to the conventional one (20-25 cm)	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1283/
Switzerland	**Minimization of herbicide application in conservation agriculture**	Experiments and a high level of knowledge have shown that there are ways to reduce and optimize the use of herbicides in agriculture of Switzerland	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1259/
Switzerland	**Maize strip tillage**	Tillage system in the cultivation of maize	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1010/
Sweden	**Water tolerant crops**	Cultivation of crops tolerant to a high level of groundwater	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1286/
Turkey	**Rotational Grazing**	Rotational grazing in areas with natural pastures	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1398/
Turkey	**Strip farming**	A method of sowing crops (mainly cereals) in strips of 50 cm wide; strips are perpendicular to wind direction	https://qcat.wocat.net/en/wocat/technologies/view/technologies_995/
Turkey	**Woven Wood Fences**	Woven wood fences as an effective and relatively inexpensive way to protect soil from erosion on slopes	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1535/

Country	Name of SLM technology	Short description of SLM technology	Link
Turkey	**Drip irrigation**	Drip irrigation	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1014/
Turkey	**Fodder Crop Production**	Regular production of fodder crops to feed livestock and improve soil properties	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1015/
Ukraine	**Создание экологически-сбалансированных агроландшафтов для повышения плодородия орошаемых почв и получения качественной сельскохозяйственной продукции**	Mixed farming with optimal ratio between crops adapted to ecological conditions	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1770/
United Kingdom	**Conservation agriculture**	Improved soil management based on minimum soil tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_987/
United Kingdom	**Conservation tillage in UK arable cropping systems: Tivington**	Surface cultivation of up to the top 10cm of soil but not a complete inversion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_983/
United Kingdom	**Soil pH management**	Acidification treatments applied to improved pastures in an attempt to restore plots to a semi-natural state	https://qcat.wocat.net/en/wocat/technologies/view/technologies_1727/
United Kingdom	**Minimum tillage in UK arable cropping systems: Tivington**	Non-inversion tillage	https://qcat.wocat.net/en/wocat/technologies/view/technologies_984/
United Kingdom	**Conservation tillage in UK arable cropping: Loddington**	Surface cultivation of up to the top 10cm of soil, non-inversion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_985/
United Kingdom	**Non - inversion tillage in UK arable cropping; Loddington**	Surface cultivation of up to the top 10cm of soil, non-inversion	https://qcat.wocat.net/en/wocat/technologies/view/technologies_986/
United Kingdom	**Direct drilling for UK arable cropping systems: Normanton**	Crop establishment with minimal soil disturbance	https://qcat.wocat.net/en/wocat/technologies/view/technologies_982/

Annex 2. Overview of the SLM approaches documented in the WOCAT database by European countries (as of early October 2018)

Country	SLM approach	Short description of the SLM approach	Link
Belgium	**Introduction of conservation agriculture in a highly mechanised agricultural system**	Combination of dissemination of the SWC technology, non-inversion tillage and research	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2556/
France	**Constructions en pierres sèches**	Construction of dry walls, troughs, etc.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2676/
Greece	**Cooperative for Drilling and Exploiting a Private Water Well**	A cooperative of landowners and at least one water rights owner established to jointly establish and manage a private freshwater well.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2619/
Greece Grčka	**Sustainable development of olive groves I**	Sustainable development of olive groves by applying no tillage operations	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2427/
Greece	**Sustainable development of olive groves II**	Sustainable development of olive groves by applying no tillage operations and plastic nets on the soil surface	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2429/
Greece	**Sustainable development of olive groves III**	Fertilizing of olive groves and maintaining soil fertility	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2430/
Greece	**Sustainable use of water**	Sustainable use of water	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2428/
Greece	**Combating Soil Salinization**	Use of freshwater to combat soil salinization	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2576/
Netherlands	**Regional process, social innovation**	Social innovation for sustained soil organic matter, clean drinking water and sustainable crop production	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2523/
Iceland	**Participatory cost - sharing restoration programme**	Collaboration between farmers and a governmental institute on rangeland restoration and improved land management	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2599/

Country	SLM approach	Short description of the SLM approach	Link
Italy	**Carbon farming**	Managing land, water, plants and animals to meet the landscape restoration, climate change and food security.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2607/
Italy	**Rural development programme in the Veneto region**	Developing rural areas in the Veneto region through sustainable land management policies	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2598/
Italy	**Municipal forest management plan - MFMP (decade 2010 - 2019)**	Management plan for silvopastoral areas with a ten-year intervention plan	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2494/
Cyprus	**Community - based maintenance and rehabilitation of agricultural terraces in mountain environments**	Maintenance and rehabilitation of traditional dry-stone terrace walls for agricultural use, through science-society cooperation, community engagement and motivation, and assistance to land users	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2537/
Hungary	**Conservation tillage**	Non inversion, conservation tillage	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2552/
Hungary	**Conventional (contour - line and ploughing) tillage**	Conventional contour line tillage	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2650/
Norway	**Regional Environmental program**	Regulations and financial grants for the reduction of pollution and promotion of the cultural landscape.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2596/
Germany	**Open dialogue platform on sustainable land management**	Establishing a dialogue platform on sustainable land management which is open to all stakeholders	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2605/
Germany	**Stakeholder participation in integrated assessment and planning of vulnerable coastal regions**	Stakeholders have been involved in integrated assessment to develop action-oriented land use options addressing possible climate change adaptation measures	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2597/
Germany	**Mobile Community Garden**	A community-supported mobile urban farm,	https://qcat.wocat.net/en/wocat/app

Country	SLM approach	Short description of the SLM approach	Link
		which serves the goals of vegetable production, and place of learning and knowledge sharing	roaches/view/approaches_2603/
Poland	**The prevention of soil sealing**	Map-based planning of land management aimed at reducing or eliminating soil sealing in agricultural land	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2540/
Portugal	**Forest Intervention Area (ZIF)**	Forest Intervention Area is a territorial unit, where the main land use is forestry. This approach assembles and organizes small forest holders and defines a joint intervention for forest management and protection.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2588/
Romania	**Information and awareness raising for safe use of metal contaminated land**	This approach aims to increase the awareness about the risk related to agricultural use of contaminated land and to present the appropriate technologies for sustainable use of contaminated land in order to reduce the transfer of contaminants into the food chain.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_570/
Russian Federation	**Field days**	Field days are events for regional stakeholders where thy discuss their demands regarding scientific help, and to be informed about new recommended practices	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2617/
Russian Federation	**Concerted thinking on common problems of water scarcity**	This approach, inter alia, implies the testing and dissemination of water-saving irrigation techniques	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2426/
Russian Federation	**Vocational Training**	Regular in-service training of farmers led by experts in land management and farm	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2544/

Country	SLM approach	Short description of the SLM approach	Link
		management	
Slovakia	**The programme of landscape revitalization and integrated river basin management in the Slovak republic for the year 2011 - retention measures in the Sobotište village**	Landscape revitalization programme and integrated river basins management in the Sobotište village	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2680/
Spain	**Caso de estudio del Guadiamar**	In 1999 and 2000, land use and soil conservation measures were developed to reduce the mobility of trace elements in the soil	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2528/
Spain	**Plan of preventive silviculture (PSP): implementation of firebreak network within a forest intervention area (ZAU)**	A pilot project for the establishment of firebreaks in forest areas aimed at preventing the spread of forest fires	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2590/
Spain	**Regional rural development programme**	Regional development programme to protect natural resources and stimulate rural economies	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2419/
Spain	**Fruit trees under biodynamic agricultural management in southern Spain**	Promotion of fruit trees growing under biodynamic agricultural management in southern Spain	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2689/
Spain	**Análisis temporal de la evolución de la contaminación**	Analysis of the evolution of contaminations in affected areas. Collecting information on climatic variables and soils at representation points, spatial-computational analysis	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2609/
Spain	**Promoting Sustainable Agriculture in Citrus Orchards**	Promoting sustainable agricultural practices and conservation of the environment in a citrus orchard in Vega Baja region	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2058/
Switzerland	**Soil support program for conservation agriculture**	Incentives to farmers applying conservation agriculture measures on their land over a	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2525/

Country	SLM approach	Short description of the SLM approach	Link
		period of a minimum 6 years	
Switzerland	**Direktzahlungssystem**	Financial benefits provided by the Federal Government in compensating farmers' income losses. The system of direct payments leads to a decrease in the prices of agricultural products for the consumers	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2601/
Switzerland	**Subsidies for conservation agriculture**	Along with the program of support of the Berne canton, land users participating in the program also receive direct payments for the application of good tilling practices. The project lasts 6 years.	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2632/
Switzerland	**Farmer initiative within enabling environment**	Initiative and innovations of land users stimulated by the government's financial and technical support	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2623/
Sweden	**Using water tolerant crops on cultivated peat soils, Recare**	Promotion of cultivating groundwater tolerant plant, with the aim of establishing sustainable peatland management	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2667/
Turkey	**Minimum Water Use**	Promotion of a drip irrigation system	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2424/
Turkey	**Fodder Crops Production**	Production of fodder crops (primarily legumes and grasses) for livestock feed	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2425/
Turkey	**Crop Production**	Promotion of the strip cropping-fallow-strip cropping system	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2423/
Turkey	**Pasture Management**	Promotion of a rotational grazing system	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2564/
United Kingdom	**Soil management initiative**	Independent organization promoting the adoption of appropriate soil management practices, especially conservation agriculture in England	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2620/

Country	SLM approach	Short description of the SLM approach	Link
United Kingdom	**Soil pH management**	Acidification of soil on intensive pasture aimed at reducing their productivity and restoring plots to low-intensity grazing land	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2615/
United Kingdom	**Participatory on - farm resarch and demonstration in UK arable cropping**	Activity aimed at identifying, demonstrating and applying the better ways of managing the land	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2547/
United Kingdom	**Participatory on - farm demonstration in UK arable cropping: Loddington**	Provision of expert knowledge in the application of appropriate or innovative equipment, and setting up small-scale trials	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2639/
United Kingdom	**Individual experimental farmer: Tivington**	Individual farmer experimenting with machinery to maintain economic viability and reduce time spent on land preparation	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2638/
United Kingdom	**Individual experimental farmer: Normanton**	Individual farmer seeking information and experimenting with machinery to maintain economic viability	https://qcat.wocat.net/en/wocat/approaches/view/approaches_2637/

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